NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

NON-LOGISTICS BAR CODE USES FOR THE DEPARTMENT OF DEFENSE: ILLUSTRATIVE APPLICATIONS FOR THE NAVAL POSTGRADUATE SCHOOL

by

Jerry J. Coady

March 1987

Thesis Advisor: Roger D. Evered

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Attendance Monitoring System and the NPS Bachelor Quarters Inventory Management System. Major recommendations for future research deal with computer support, funding and cost/benefit analysis.

Non-Logistics Bar Code Uses for the Department of Defense: Illustrative Applications for the Naval Postgraduate School

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

This thesis examines the use of existing bar code technology as a means of increasing efficiency and accuracy in the performance of administrative tasks within Department of Defense agencies. Motivated by increasing labor costs, both the private and public sectors have implemented bar code based control systems in a myriad of applications. While the public sector has concentrated on the logistics applications of bar coding through LOGMARS, the private sector has expanded their use of bar code based data entry and management control systems. The focus of this study is directed toward a comparative analysis of the non-logistics bar code applications prevalent in the private sector as potential applications within the DOD. Two specific areas at the Naval Postgraduate School are analyzed as potential bar code test applications for reducing manhours and increasing accuracy in the performance of administrative tasks; namely the NPS Attendance Monitoring System and the NPS Bachelor Quarters Inventory Management System. Major recommendations for future research deal with computer support, funding and cost/benefit analysis.

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I. INTRODUCTION

History reveals that methods of data collection and entry into a control system have evolved from scribblings on a cave wall through operator keyed entries to the automated data entry systems of today. Automated data entry is simply a means of collecting information that minimizes or eliminates human operator involvement. Though there are a variety of ways to automatically enter data into a control system, this study specifically addresses bar coding.

In addition to identifying non-logistics applications and uses of bar code technology, five basic questions come to mind. These questions include: What is bar coding? Who uses it? How is it used? Why is it used, and when is it beneficial? Although these basic questions may not be explicitly addressed in the context of this thesis, the reader who didn't already have the answers will, at minimum, have strong feelings about the potential uses and benefits of bar coding. These potential uses and benefits are only limited by your imagination and creativity.

A. BACKGROUND

Bar code technology has progressed from a relatively unused pattern of black and white bars on a few grocery items in the early 1970's, to "the" major means of automated data transactions today. The Department of Defense has

proved to be a key player in the increased acceptance and use of bar code technology. A Joint Steering Group for Logistics Applications of Automated Marking and Reading Symbols (LOGMARS), chartered by the Assistant Secretary of Defense, completed a five year study in 1981 which established procedures for the use of bar code technology throughout the Department of Defense. In 1982, the issuance of MIL-STD-1189 provided additional impetus by requiring a bar code label on all items shipped to the Department of Defense. This order affected 50,000 Department of Defense suppliers. [Ref. 1:p. 1]

Though the emphasis on the use of bar code technology within the Department of Defense clearly resides in logistics applications, the private sector has expanded its utility. As a part of this move toward expanding the use of bar code technology, the Naval Postgraduate School may well be the ideal proving ground for the Department of Defense applications.

B. OBJECTIVE

The objective of this research is to evaluate the use of bar code technology beyond purely logistics applications. This is being done by identifying areas at the Naval Postgraduate School which are similar to private sector applications and which should be addressed before Department of Defense wide authority and guidance are issued and disseminated.

C. SCOPE, LIMITATIONS AND ASSUMPTIONS

This study focuses on the implementation of bar code technology as a means to increase efficiency and accuracy in the performance of routine and recurring administrative tasks at the Naval Postgraduate School. Private sector uses of this technology outside the typical logistics and inventory control arena are presented to provide a basis for comparison and analysis of this effort. Public sector experiences beyond LOGMARS applications are virtually nonexistent; therefore, selected LOGMARS applications are presented to provide a background and contrast to this study.

The proposed areas for implementation of bar code technology at the Naval Postgraduate School are based on current procedures employed there. They are only examples and should not be considered exhaustive of the possible applications at NPS. They may however be assumed to apply to other Department of Defense activities in their respective or similar situations. Though the scope of this study is necessarily limited to selected applications of bar code technology at the Naval Postgraduate School, the potential benefits to the Navy and other Department of Defense agencies should not be limited by this scope.

The study does not attempt to quantify the potential for future personnel reductions as a result of manhour savings through the use of bar code technology; nor does it

specifically identify the costs associated with procuring, installing, and maintaining the required equipment. Additionally, the computer technology, support, and technical factors required for full implementation of recommended bar code applications are not addressed. These areas will be included as suggestions for future research.

The reader may not be familiar with the phraseology used throughout this thesis; hence a glossary of selected acronyms, words, and terms is presented in Appendix A.

D. RESEARCH METHODOLOGY

As initial literature search was conducted to review regulations, reports, policy guidance, trade journals, and industrial literature applicable to the utilization of bar code technology. Historical data on bar code technology and LOGMARS were obtained from the Defense Logistics Studies Information Exchange, Fort Lee, Virginia, and the Fleet Material Support Office, Mechanicsburg, Pennsylvania.

Additionally, interviews were conducted either in person or by telephone at the following organizations:

1. Administrative Sciences Department, Naval Postgraduate School, Monterey, California

2. Bachelor Quarters, Naval Postgraduate School, Monterey, California

3. Dudley Knox Library, Naval Postgraduate School, Monterey, California

4. The Federated Group, City of Commerce, California

5. The Federated Group, Dallas, Texas

6. Fleet Material Support Office, Mechanicsburg, Pennsylvania

7. Florida Regional Library for the Blind and Physically Handicapped, Daytona Beach, Florida

8. Judicial Council of California, San Francisco, California

9. Louisiana State University, Baton Rouge, Louisiana

10. Monterey Public Library, Monterey, California

11. Navy LOGMARS Project Office, Washington, D.C.

12. Navy Medical Administrative Unit, Presidio of Monterey, Monterey, California

13. Recreational Services Office, Fort Ord, California

14. Texas Instruments, Inc., Dallas, Texas

15. The Wherehouse, Monterey, California

The initial literature research enabled the five basic questions about bar coding (page 11) to be answered.

The data collected in the course of this study provided the basis for a comparative analysis of the non-logistics bar code applications prevalent in the private sector as potential applications within the Department of Defense. Specifically, interviews with the Naval Postgraduate School Administrative Sciences Curricular Officer and the Bachelor Quarters Officer suggested two areas as possible bar code test applications for reducing manhours and increasing accuracy in the performance of administrative tasks. These two means, namely: a) attendance monitoring, and b) BQ inventory management, were then examined for possible for code application.

A comparative analysis was then undertaken to indicate the possible savings in man-hours and dollar expenditures to perform the above two administrative tasks: a) by the current way, and b) with the use of a bar code system. The extension of the savings enabled a number of recommendations to be made for improving DOD administration.

E. THESIS ORGANIZATION

This chapter briefly defines automated data entry, presents five basic questions regarding research which specifically address bar coding, identifies the Department of Defense as a key player in the advancement of bar code technology through LOGMARS, and presents the objectives and methodologies of this study. Chapter II defines bar codes and traces the historical development of bar code technology. Chapter III examines selected applications of bar code technology in the private and public sectors. Chapter IV is a comparative analysis of non-logistics bar code applications found in the private sector and current Department of Defense administrative procedures. Since the findings of such an analysis could appear as very broad and vague without examples, two specific areas at the Naval Postgraduate School are addressed. Chapter V presents the conclusions of this study and lists recommendations for future research. The conclusions are presented through a look at bar codes and their future and as considerations for implementing a bar code based management and control system.

II. BACKGROUND

Automated data entry into a control system falls within one of three main categories [Ref. 2]:

- Radio frequency, which is based on a device's ability to transmit a radio frequency that in turn invokes a response from a second device.
- Magnetic, which employs the encoding of a magnetic film or strip that is sensed by a magnetic detector.
- Optical, which use light, visible or invisible, that is reflected or absorbed by a printed pattern and sensed by some type of light sensing element and decoded.

This study concentrates on optical automatic data entry systems, specifically bar coding. All of the automated data entry methods have their advantages and disadvantages and their comparison is presented in Appendix B. However, bar coding is the least expensive, the most broadly applicable technique, and the Department of Defense standard.

A. DEFINITION

A bar code is a printable machine language which reproduces the bit-streams of ones and zeros which are the basis for the internal logic of all digital computers. When organized into a particular pattern, these bit-streams represent an alphanumeric character which can be read by instruments and communicated directly to a computer. [Ref. 1:p. 1]

These ciphers or bytes are constructed from a series of dark and light bars organized into various patterns which represent letters, numerals, and other human-readable symbols. While there are many different bar code formats, the major difference between them is the relative position and width of the dark and light bars and the number of elements used to symbolize a character. [Ref. 1:pp. 26-29]

Figure 2.1 illustrates the character structure of a typical bar code. The symbol illustrated is Code 39 (3 of 9) for the character "6."

B. HISTORICAL EVOLUTION

The roots of bar coding can be traced to pre-World War II and the desire to develop more efficient grocery stores. In 1932, a punch-card based system developed at the Harvard Business School to automate supermarkets was shunned because labor costs were too low to justify its implementation. [Ref. 3:p. 14]

As wages rose after the war, the idea of automated checkout counters became more economically attractive. But as ideas were examined and discarded, the common thread was electronics. The technology needed to develop a cost effective system lagged behind the ideas and perceived need.

1. Woodland and Silver

On October 20, 1949, Norman J. Woodland and Bernard Silver filed a patent application for a symbology which automatically classified things by identifying patterns.

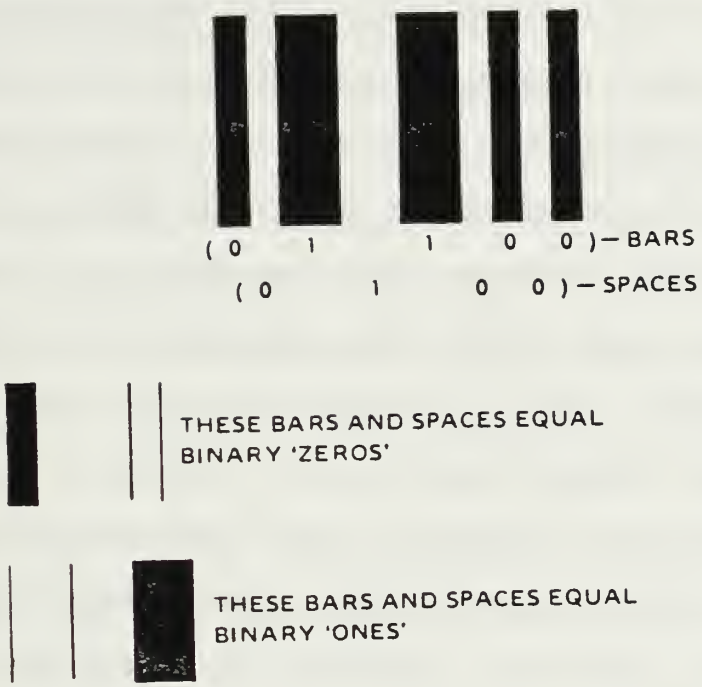


Figure 2.1 Bar Code Character Structure
[Ref. 4:p. 32]

Appendix C contains a copy of the figures filed in their patent application.

Not only did Woodland and Silver develop the first optical bar coding symbology, but they also developed the equipment that automatically scanned the symbol and took action based on the scanned information. It is not surprising that one of the applications described in detail in their patent application was for the supermarket.

Their basic symbology consisted of four white lines on a dark background that resulted in a three-digit binary code capable of representing seven different classifications. They noted, however, that the addition of more lines would increase the information carrying capacity. For example, a symbol with 10 bars could be used for 1,023 classifications. [Ref. 5:p. 20]

Although most histories list the Woodland and Silver symbology as a "bull's eye" symbol, their basic symbol was a straight line which is similar to today's bar code symbology. They felt that the straight line pattern was limited by specific orientation to the reader; while a circular pattern could be scanned regardless of orientation. [Ref. 5:p. 20]

Perhaps the most important part of the Woodland and Silver patent application was their bar code scanning equipment. It consisted of a transparent conveyor belt with two bright lights underneath. When an item passed over an

optical scanning element (symbol side down), it continued to a delivery chute if the symbol was recognized; if not, it was placed on a return conveyor to be reread. [Ref. 5:p. 22]

Norman J. Woodland and Bernard Silver are now only obscure cornerstones in the history of bar coding, but their innovations spurred the bar code technology of today.

2. The Emergence of Bar Coding

In the late 1960s, the laser and microprocessor were the impetus needed to incite bar code technology. In fact, what the wheel did for transportation, the microprocessor did for bar coding. [Ref. 3:p. 14]

With the microprocessor (or minicomputer), systems took on a new meaning. They integrated a data base with scanning and printing devices and system costs sharply declined. These lower costs created a surge in the bar coding market and the technology continued to advance.

As suggested by Woodland and Silver almost twenty years earlier, supermarket chains were the target. In 1970, a successful circular bar code had been scanned in a demonstration at Kroger, and the supermarket industry formed its Ad Hoc Committee on Universal Product Coding. Thus, many historians conclude that the history of bar coding began sixteen years ago, when it came out of the laboratory.

3. Universal Product Code

Competition ruled, and the free market inspired the opportunity to develop and have adopted one's own code. Over the years, anywhere from 50 to 150 different bar codes have been developed, but only a handful are used (Appendix D contains a comparison of the most popular codes) [Ref. 3:p. 62]. However, the successful implementation of bar coding in the grocery industry depended upon the scanning community and the food producers and dealers adopting the same standard.

Acceptance of one standard code for the grocery business did not happen overnight, but on April 3, 1973, bar coding got the push it needed. The Universal Product Code (UPC) was adopted as the standard for the grocery industry. This swelling of enthusiasm by grocers for automated checkout counters and inventory control has continued with more than 13,500 scanning stores at the end of 1985 and an estimated 20,000 by the end of 1986. [Ref. 6:pp. 22-26]

4. Two Major Divisions of Bar Coding

At 16 years of age, the supermarket bar coding industry is relatively mature and knows exactly where it is today and pretty much where it will be ten years from now. On the other hand, industrial bar coding, the second major division, is more of a maverick and less predictable.

A catch-all phrase for all applications except those at the supermarket checkout counter, industrial bar coding enjoys an excitement not found in the supermarket side. Unlike its counterpart, industrial bar coding does not refer to a common application; but is used in a number of unique ways. It can be found keeping track of hospital supplies, laboratory processes, court records, library books, video-tape rentals, college football tickets, office records, and even transactions and money in banking.

Wherever bar coding is used, the bottom line is the same. It's the technology of choice for an inexpensive automated data entry format when a computerized record of transactions are either required or desired. [Ref. 3:p. 14]

5. <u>Trials and Tribulations of Industrial Bar Coding</u>

About the same time that the supermarket industry was advancing its bar code technology through automated checkout counters, another industry was developing its own system, but without the success of Universal Product Codes.

In 1967, the North American railroad industry, seeking to keep track of more than two million freight cars scattered across the country, developed a bar code system; and by 1974, 95 percent of the nation's freight cars had been bar coded. Unfortunately, they experienced only a 40 to 50 percent read rate, and by the mid-1970s, the system was largely defunct, except for a few closed railroads. [Ref. 3:pp. 16-19]

This failure in the railroad industry was caused neither by the lack of technology nor standardization. The problem was maintenance, or more specifically, failure to wash the labels regularly. [Ref. 3:pp. 16-19]

The technology had been developed; so unlike the grocery industry in its infancy, industrial bar coding had only one major obstacle to overcome, standardization.

6. Industry Moves Towards Standardization

One industry deciding on a standard bar code and requiring all of its suppliers to use it had been proven by the grocery industry and other point-of-sale operations as the most effective means of implementing bar coding. What Universal Product Codes had done for supermarkets, proved promising for industry as a whole.

In the late 1970s, several ad hoc groups were organized to investigate and/or implement industry-wide programs involving machine readable technologies. And, the technology of choice was bar coding. According to ScanJournal [Ref. 6:pp. 24-25] the three most significant groups included:

a. LOGMARS

The Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) was implemented in July 1982, by the Department of Defense. This bar code program affected all Department of Defense agencies and its 50,000 suppliers [Ref. 1:p. 1]. Bar coding within the industrial

division earned increased levels of credibility and promise through their economic justification studies, technical evaluation reports and documented field tests.

b. AIAG

Unlike the Department of Defense, the bar code standards for the Automotive Industry Action Group (AIAG) were voluntary for all five major U.S. automobile manufacturers. However, industry-wide standards released between 1983 and 1984 have impacted more than 16,000 suppliers as well as the industry itself. [Ref. 6:p. 25]

c. DSSG

The Distribution Symbology Study Group (DSSG) took Universal Product Codes (UPC) to the shipping containers carrying UPC marked products. The well documented technical work of this group opened new opportunities for users to benefit from bar coding. Though this study went public in 1981, its benefits have yet to be publicized. [Ref. 6:p. 25]

Nothing succeeds like success, and standardization in industrial bar coding appears to be the key to the entrenchment of bar code technology. However, all industries should not be expected to adopt the same bar code symbol. Although the industry leaders recognize the fact that using one symbol would be ideal, it is extremely unlikely for a number of reasons, not the least of which is the amount of time, effort, and capital that have gone into

standardizing their individual industries. Thus, co-existence with other industry standards is an accepted fact of life.

7. Historical Review

Post World War II technology and rising wages provided the impetus for developing a cost effective automated data entry system, specifically bar coding. There were numerous events which led to the evolution of today's bar code technology. As a review, the most significant events are listed below.

1949--Patent for bar code symbol and reading equipment filed by N.J. Woodland and B. Silver.

1970--Successful supermarket bar code demonstration at Kroger.

--Formation of U.S. Supermarket Ad Hoc Committee on Universal Product Coding.

1973--Universal Product Code (UPC) symbol adopted.

1974--Code 39 (3 of 9) developed.

1976--Joint Steering Group chartered by the Department of Defense for LOGMARS study.

1980--Code 39 adopted as Department of Defense standard.

1981--LOGMARS final report published.

1982--MIL-STD-1189 issued by the Department of Defense in support of LOGMARS implementation.

--Department of Defense replaced its Joint Steering Group with the LOGMARS Coordinating Group.

1983--Navy LOGMARS Program Office established.

1984--MIL-STD-1189 superceded by MIL-STD-1189A.

--Fleet Material Support Office LOGMARS Project Officer appointed.

C. LOGMARS

LOGMARS, an acronym for Logistics Applications of Automated Marking and Reading Symbols, has become synonymous with bar coding within the Department of Defense, and to a large extent, industry wide.

In 1976, the Department of Defense (DOD) chartered a Joint Steering Group to conduct a study and establish a standard machine-readable symbology for DOD use. The Joint Steering Group membership consisted of representatives from the four uniformed services, the Defense Logistics Agency, the Military Traffic Management Command, and the Military Airlift Command. A Senior Advisory Group was also appointed to monitor the LOGMARS project at the Department of Defense level. [Ref. 7:p. 27]

The LOGMARS project primary objective prevented a duplication of effort within the Department of Defense in implementing automated marking and reading. Its long-range objective was to improve productivity, timeliness, and accuracy in logistics and thereby reduce costs.

The project also established procedures for use of the symbology. It would be used to automate manual entry systems or be incorporated into existing automated systems within Department of Defense logistics functions. LOGMARS would not recommend system changes solely to accommodate the use of its symbology. Automated data entry would be viewed

as an enhancement to an existing automatic data processing system and not as a separate system in itself.

The Joint Steering Group conducted laboratory and proto-type test programs to evaluate the benefits of automated data entry compared to manual methods. Tests included the Code 39 (3 of 9) bar code and Optical Character Recognition, Style A (OCR-A). Equipment, printing and documentation, and the printing of symbologies directly on packaging materials were tested in the functions of shipping, receiving, inventory and location survey, issue, and tracking. [Ref. 7:p. 28]

The Code 39 bar code proved it could be used by operating personnel in the functions tested to reduce processing time and increase accuracy and efficiency. This success gave the Department of Defense some pilot areas for implementation of the Code 39 bar code. And, on October 9, 1980 the Department of Defense approved code 39 as the standard symbology.

The Joint Steering Group completed its extensive five year study and published its findings in September 1981. Then in January 1982, the Department of Defense issued Military Standard 1189 (MIL-STD-1189), titled "Standard Symbology for Marking Unit Packs, Outer Containers, and Selected Documents," to support the implementation of LOGMARS. Accordingly, commercial vendors and Department of Defense activities were required to mark individual items,

unit packs, outer containers, and selected documentation with Code 39 bar code symbology. This requirement ultimately affected over 50,000 DOD suppliers. In September 1984, Military Standard 1189A (MIL-STD-1189A), titled, "Standard Department of Defense Bar Code Symbology," replaced MIL-STD-1189 and is presented in Appendix E.

Subsequent to the tests conducted by the Joint Steering Group, additional applications have been tested by Department of Defense activities outside those in the LOGMARS test program.

The areas tested in the LOGMARS program were primarily keyed to logistics functions. Therein lies the primary objective of this thesis; to identify sample areas within the Department of Defense, specifically the Naval Postgraduate School, where the implementation of bar code technology will reduce processing time and increase accuracy and efficiency in administrative tasks.

III. PRESENTATION OF DATA AND SPECIFIC APPLICATIONS

Over the years, the high cost of labor and limited manpower resources have taken their toll in both the private and public sectors. This is particularly true in labor intensive and service organizations. With the passage of the Gramm-Rudman-Hollings Bill, the old adage of doing more with less took on new meaning in the public sector. Reductions in services and hiring freezes were the orders of the day; yet, the requirements for those services continued to increase.

Obviously, the adoption of the Gramm-Rudman-Hollings Bill had no affect on the bar coding systems used today in either the public or private sectors. Its future influence on the private sector will be little, if any. However, the public sector must find ways to cut costs while meeting both current and emerging requirements.

A distinct move toward automated data entry can be traced to increasing labor costs and advanced technology which reduced the cost of automation. Perhaps the dream (or requirement) to do more with less is not as elusive as it once was. Automated data entry through bar codes, while not the solitary answer to all budgetary constraints or problems, is a proven means of improving productivity,

timeliness, and accuracy in data collection and management without an increase in manpower.

The remainder of this chapter presents a brief overview of the growth and application mix in the bar code market. Additionally, private sector cases relating to the specific utilization of bar codes, outside purely logistics applications, provide empirical data germane to this study. In the final section of this chapter, selected LOGMARS applications are presented as both complementary and contrasting data.

A. BAR CODE MARKET

In recent years bar coding, after a very slow start, has enjoyed enormous growth. Today, the bar code market has established itself as a billion dollar industry.

Due in part to the number of privately held companies that manufacture bar code equipment and those that include the cost of computer equipment in their reports, exact sales figures in the bar code market are difficult to obtain. Additionally, projected sales figures are clouded by imperfect knowledge of future bar code applications. However, industry experts agree that a market analysis by International Resource Development, Norwalk, Connecticut, is both reliable and accurate. [Ref. 3:p. 65]

In 1984, bar code equipment sales totaled $.562 billion and are expected to more than double in just two years. Sales for 1986 are estimated to be $1.2 billion and $1.6 billion in bar code equipment sales are projected for 1988.

[Ref. 3:p. 65] Figure 3.1 graphically displays the growth in bar code equipment sales biannually from 1984 to 1988.

An obvious question in any market analysis is: Who is using the product? Initially, in bar coding this is answered in two parts: the Government (public) and all others (private). Figure 3.2 graphically compares the share of the bar code equipment market held by the public and private sectors.

With a 3:1 share of the market, the private sector is broken into three main categories: service, industrial, and retail. Specific examples that absolutely define the three categories included within the private sector are not available. However, the following assumptions can be made: Retail, the most clearly defined, includes all point of sale activities, specifically those using UPC. Service, a nebulous term, includes both trade and professional organizations that may include, but not limited to, accounting firms, law firms, banks, universities, labor unions, etc. Finally, industrial, a catchall phrase, includes all applications not classified as retail or service. A further analysis of the application mix within the private sector is illustrated in Figure 3.3.

By definition, any application of bar code technology within the Department of Defense is under the cognizance of LOGMARS. It should be noted, however, that there are specific exceptions to the scope of LOGMARS. They include

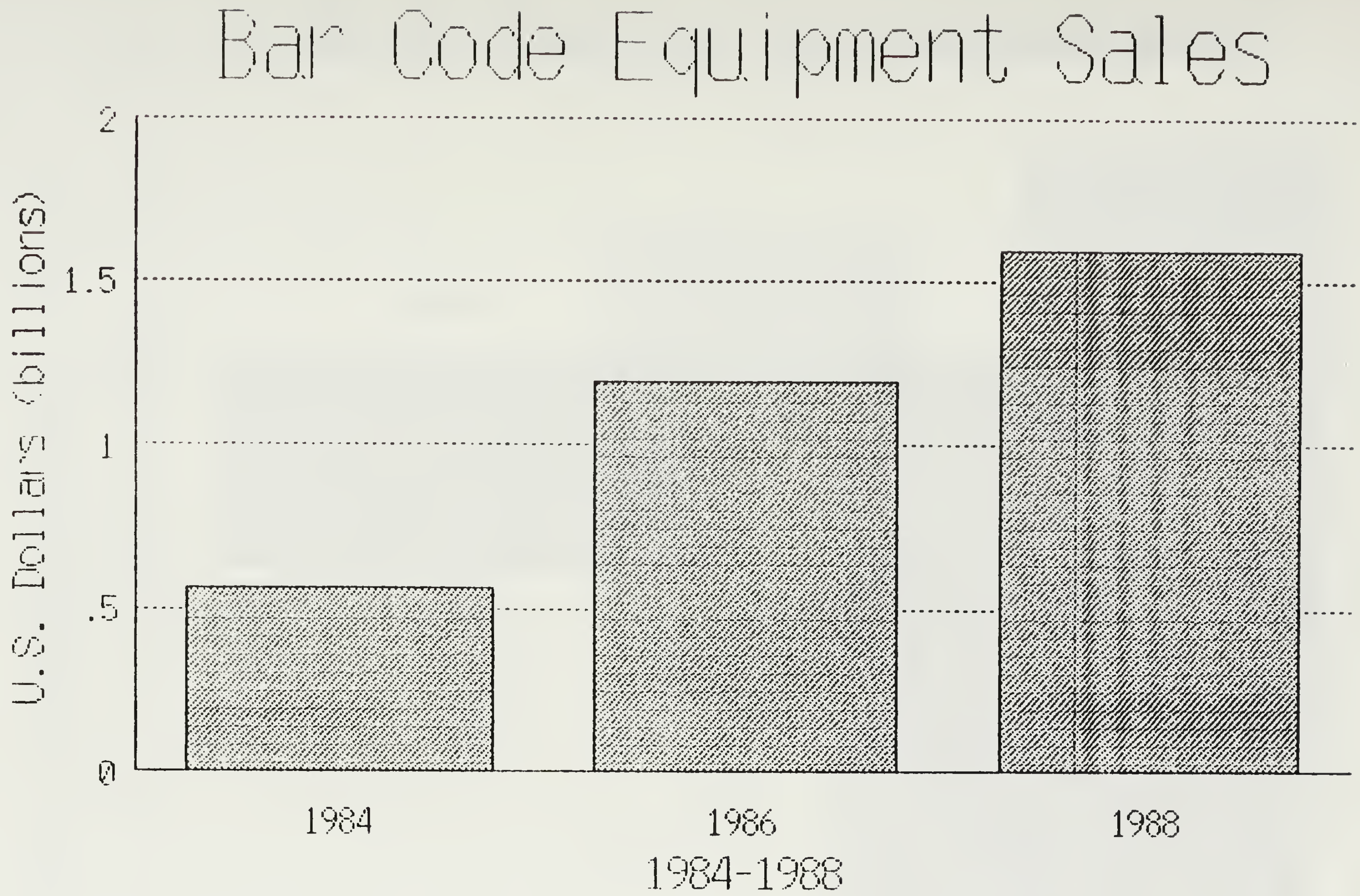


Figure 3.1 Biannual Growth in Bar Code Equipment Sales [Ref. 3:p. 65]

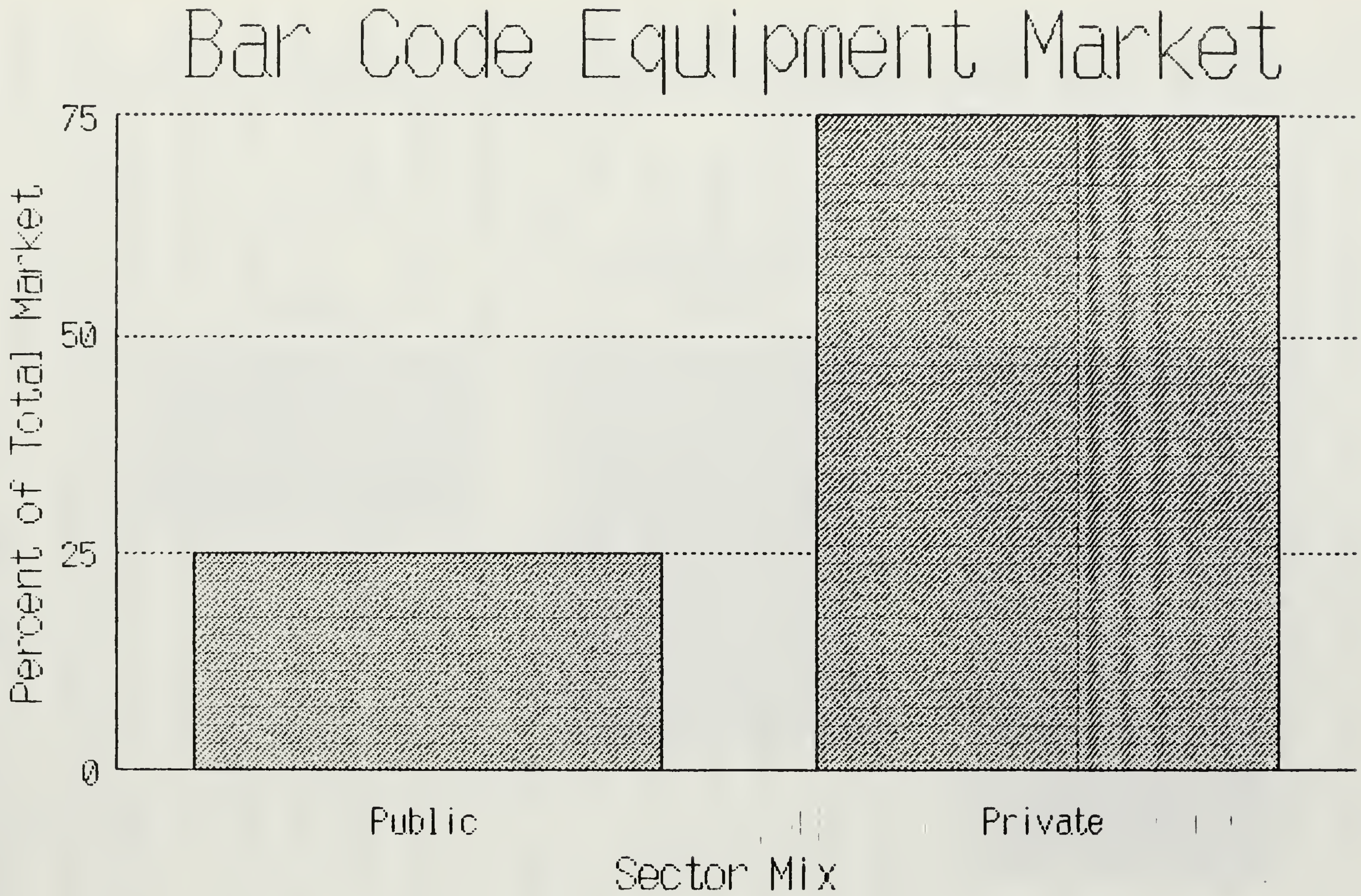


Figure 3.2 Public/Private Sector Bar Code Equipment Market Share [Ref. 3:p. 65]

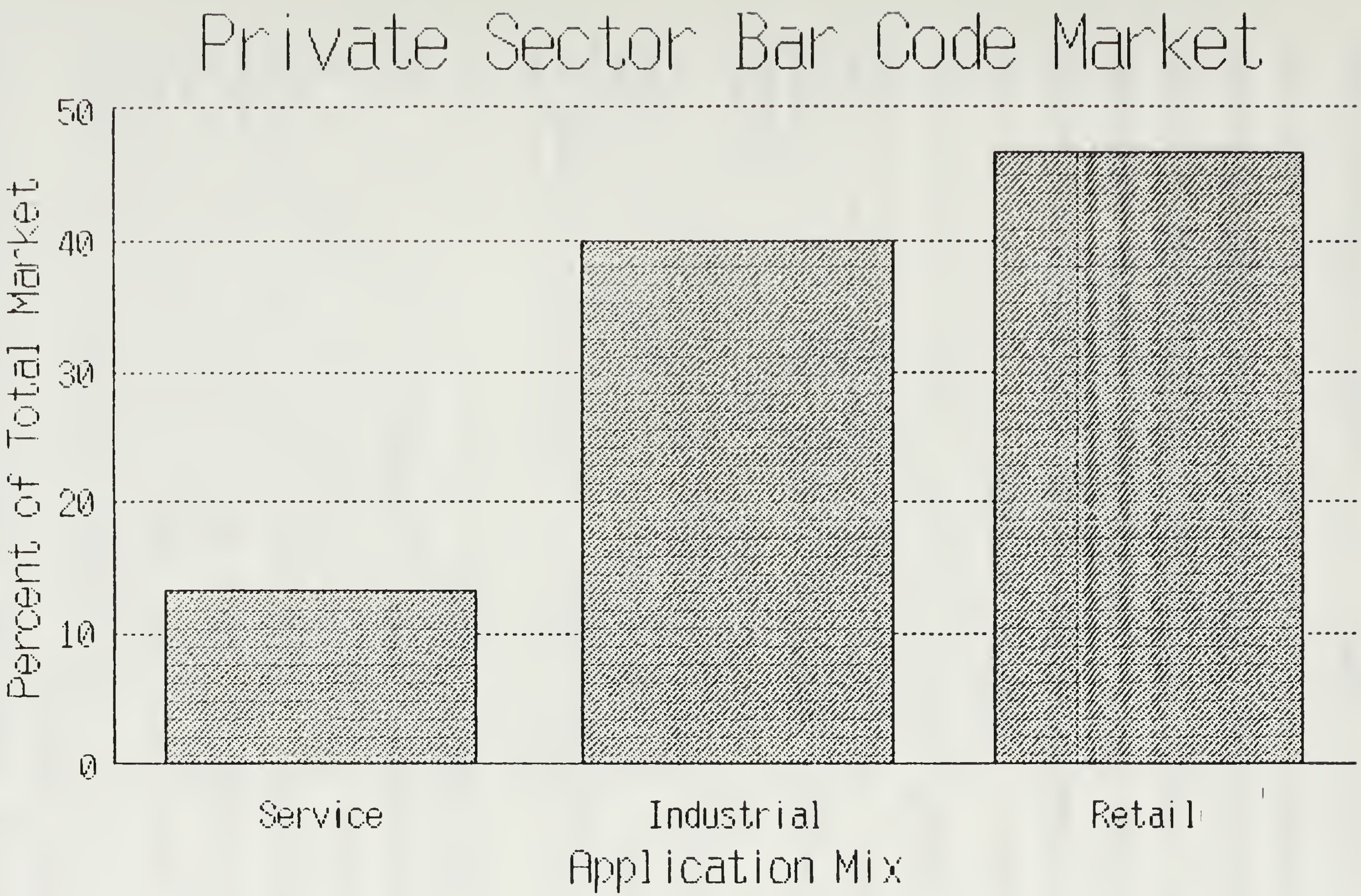


Figure 3.3 Private Sector Bar Code Application Mix [Ref. 3:p. 65]

commissary/exchange systems, bulk petroleum oils and lubricants, nuclear ordnance, and personal property/household goods. [Ref. 8] These areas either cross into the private sector through contracting, are considered retail activities and as such are included in private sector retail figures, or the data is classified and not available. Therefore, a further analysis of the application mix within the public sector is neither relevant nor available.

B. PRIVATE SECTOR

The private sector has clearly expanded the use of bar coding beyond mere inventory control and its associated applications. The cases presented in this section represent examples of areas where the private sector has utilized bar code technology in administrative functions to increase efficiency and accuracy without a corresponding increase in manpower.

1. Monterey Public Library

The Monterey Public Library maintains 115,000 volumes in their circulating material with a staff of 19 full time employees. Although the size of their circulating material is limited by space, their monthly circulation is limited by their staff size and/or their charging system. By the end of 1978, their monthly circulation was rapidly approaching full capacity.

Until May 1980, the Monterey Public Library used a microfilm charging system. This system had replaced the

obsolete card filing system with one in which all transactions were photographed (i.e., a patron's card together with the book card). The microfilm had to be manually read to get exceptions which were then put into a punch card system for sorting to generate an exception list. All overdue notifications were manually typed from this list. Reserves had to be manually sorted from material checked-in. Although it was considered superior to the card filing/charging system, according to Ruth Kelly, assistant director of the Monterey Public Library, ". . . microfilm was one of the least satisfactory systems that anybody ever invented . . . ." [Ref. 9]

In February 1979, they purchased a bar code charging system from Computerized Library Systems Inc. and began establishing their database. The system consisted of a host computer and five terminals, one equipped with a laser scanner and two with wand scanners and two that were key entry only. Even though it was considered a turnkey system, the library staff built their own database while continuing normal operations with the old system. This time consuming process was completed in May 1980 and June 1980 was the first fully operational month. Since then, their monthly circulation has continued to increase.

From the time that the Monterey Public Library's bar code charging system was fully operational until now, their circulation has increased over 19 percent without a

corresponding increase in staff. In fact, their staff has remained constant at 19 and they still have room for growth in monthly circulation. Figure 3.4 is a graphic representation of their circulation growth.

When asked if bar coding had saved the library money, Ms. Kelly stated that it was hard to put a dollar value on their savings since over the years, all costs had gone up. However, the system has eliminated a lot of terribly boring, routine tasks and they're done more accurately by the computer than people could do them. Ms. Kelly had nothing but praise for their bar coding charging system and stated unequivocally that there was no comparison between it and the old system. [Ref. 9]

Since the system has been in operation they have experienced 100 percent accuracy and it has been fully functional 97 percent of the time. When the system is down, they write down the patron codes and book codes for key entry into the system and they save checked-in material for automatic entry after the system is back on line. Although their system is capable of using a microcomputer as a backup, the low percentage of down time does not warrant implementation.

Their system is programmed to automatically send out overdue notices at selectable intervals. Additionally, a book on a reserve list is automatically flagged when it is returned. Currently their system is used only for

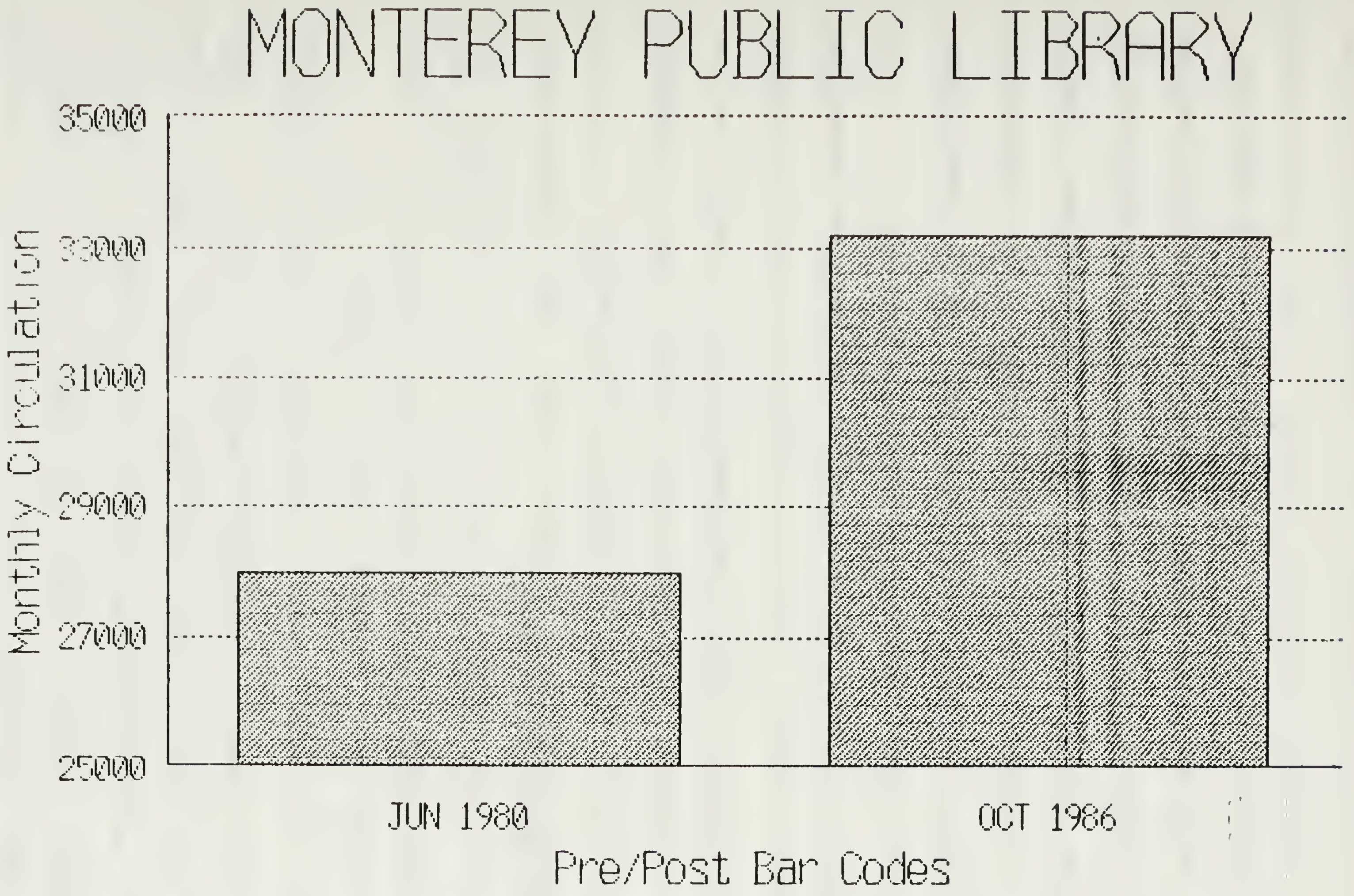


Figure 3.4 Monterey Public Library Circulation Growth

circulating material. Future plans include making it an on line catalog and the addition of a bibliography utility. [Ref. 9]

In addition to the library services which have been automated, the statistical data available through the system have proven essential to their funding. The Monterey Public Library serves both Monterey and Santa Cruz counties; therefore, data on usage by Santa Cruz county are needed for payment. Their database makes what was once a cumbersome task, very easy and completely accurate. [Ref. 9]

Despite the lack of hard dollar values, the benefits of the Monterey Public Library's bar code charging system are unquestionable. Their increase in circulation alone without an increase in staff has allowed them to better serve the community more efficiently and accurately.

2. Florida Regional Library for the Blind and Physically Handicapped

The Florida Regional Library for the Blind and Physically Handicapped serves over 21,000 people throughout the state who are legally blind and/or physically handicapped. In 1982 alone, the library staff processed over 400,000 items, including recorded disks, tape cassettes, and books in braille. With books coming in and going out at a rate of over 16,000 a week they, like the Monterey Public Library, found that demand began to exceed capacity. [Ref. 10:p. 16]

After consulting with specialists from the Standard Register Company, they installed a bar code data collection system which used a special computer-generated continuous pressure-sensitive label form for shipping. These scannable forms included the patron's name, address, and identification number, along with the book number and title. Also printed on the form are a bag number for the post office, the number of volumes, and the identification and date of issue of the book. The new system not only ensured a faster more efficient means of handling the items, but made it easier for patrons to return them to the library. [Ref. 10:p. 16]

Prior to adopting the bar code system and pressure-sensitive label, the library had been using a 96-column tabulating card imprinted with the patron's name and address and the book title, number, etc. When shipping a book out, this card was placed in a small window envelope, and the envelope was inserted into the slot of a book mailer.

The library's return address was printed on the reverse side of the envelope, which required the patron to remove it, turn it over, and replace it in the slot prior to returning the book, a seemingly simple task for someone who has full vision and muscular coordination. But, the library's patrons have, at best, limited vision and/or impaired manipulative skills which frequently made this task difficult and confusing. As a result, the cards were often

damaged and the library staff had to re-enter all of the information on these cards. [Ref. 10:p. 16]

The new system uses a 3 x 5 inch card that is cut in the upper right-hand corner and rounded on the other three on which the pressure-sensitive label is applied during production. The label's special adhesive formula allows it to be removed by the patron with little effort and leaves no residue to obliterate the return address and pertinent information on the card. The cards cut corners facilitate presorting after which the 16 character patron and book numbers are scanned and transmitted to the library's computer and their data base is automatically updated.

The system works, and works well. They can check-in over 375 cards an hour and in just two and a half hours the staff can process 5000 forms for check-out. Figure 3.5 depicts this rate as compared to the 10-12 hours required just to stuff cards into envelopes for a similar number. [Ref. 10:p. 19]

As far as the library is concerned, the new system is fabulous [Ref. 10:p. 19]. They've been able to continue to meet increasing demand without increasing their staff or exceeding capacity. Once again, bar coding has proven itself as a system that can not only increase capacity, but it can also increase efficiency and accuracy without an increase in manpower.

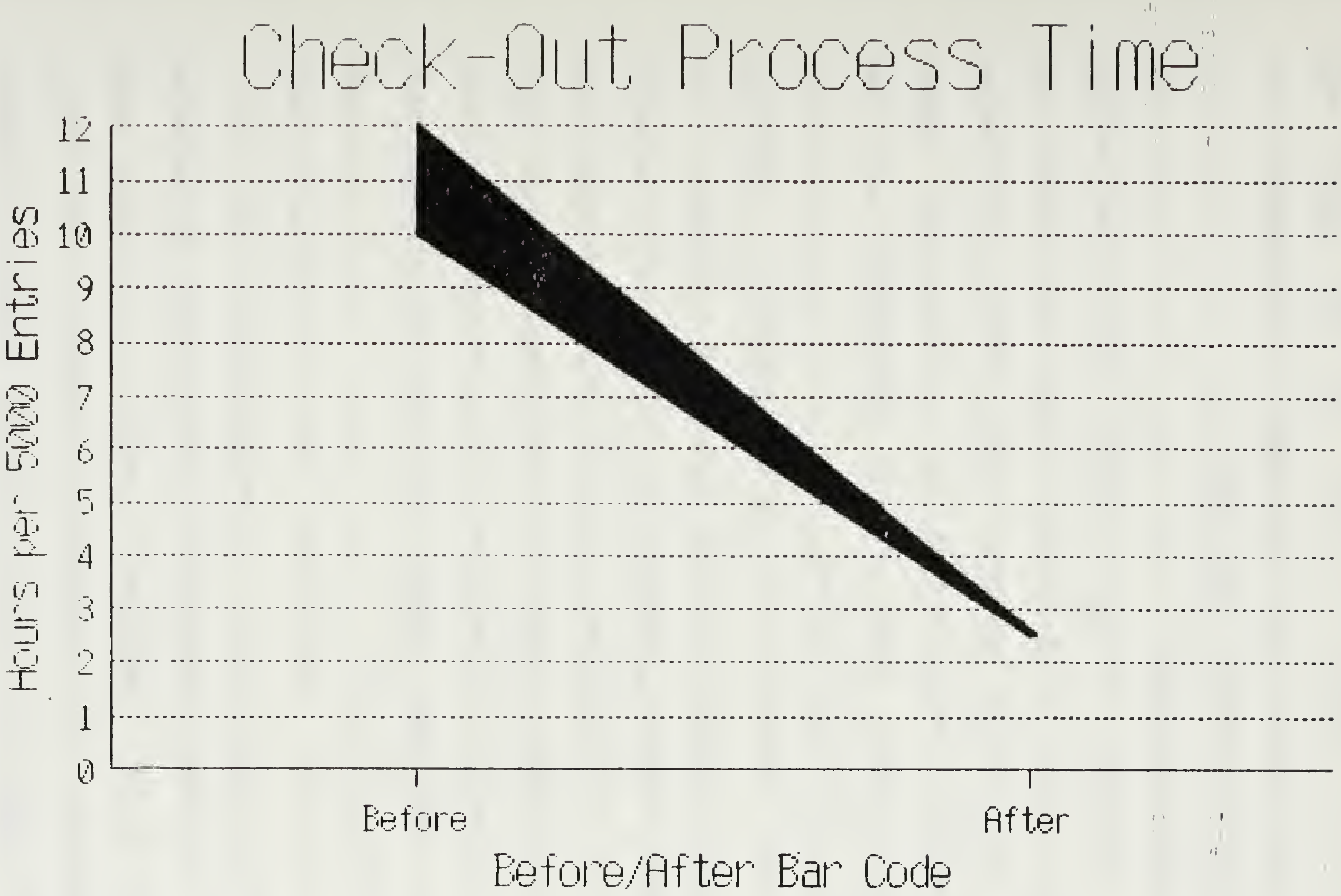


Figure 3.5 Florida Regional Library for the Blind and Physically Handicapped

Not only is this system easier and more efficient for the Florida Regional Library for the Blind and Physically Handicapped, but their patrons can depend upon prompt and accurate service from them.

3. <u>The Federated Group</u>

The Federated Group is a large audio/video retail chain with 60 stores in California, Arizona, and Texas. In addition to their retail business, video rentals comprise a major portion of their operations. This case deals primarily with their video rental department and the associated bar code applications.

Bar code standardization in an industry is normally applied for the benefit of those within it. However, the Video Software Dealers Association (VSDA), the largest organization of manufacturers, distributors, and retailers in the video industry, adopted the Universal Product Code (UPC) as the industry standard bar code. Representing over 2000 members, they went against the needs of most of its retailers. [Ref. 11:p. 25]

While the UPC, numeric-only, bar code is well suited for point-of-sale operations, it is unsuitable for rental operations. At least 90 percent of their retail membership are primarily in the business of renting videotapes and expressed the need for both alpha and numeric characters. Therefore, the decision to adopt the UPC code as the VSDA

standard is not only puzzling, but has not been adopted by most. [Ref. 11:p. 25]

Included in those who favor an alphanumeric code over the UPC are The Wherehouse and The Federated Group. Both organizations state that a videotape has a life of approximately 100 viewings, then it must be replaced. Consequently, for them to track the number of times that a specific copy of a given title has been rented, they must assign a unique code to every tape in their inventory. Among the reasons that make the UPC bar code unacceptable for rental operations, is the fact that all copies of the same title have the same code.

Both The Wherehouse and The Federated Group, as well as numerous others renting videotapes, have adopted Code 3 of 9 (the Department of Defense standard). The Federated Group selected the Code 3 of 9 alphanumeric code because of its flexibility. With it, they not only track usage, but also keep statistics on a title's popularity in order to determine whether a store has the right number of copies in their inventory.

Each rental department in The Federated Group chain maintains an inventory of 2000 plus different titles and their total rental library frequently exceeds 5000 videotapes. In addition the unique code assigned to each videotape in their inventory, video club members are issued a bar coded membership card, or a bar coded label that is

attached to the member's credit card. When entered into their database, this unique identification number is matched to a member's name, address, telephone number, credit card number (or other form of deposit), etc.

Each retail outlet in The Federated Group maintains an individual database, although cities with more than one outlet allow members to rent from any location with only one membership number. The database is automatically updated each time a particular videotape is rented. Additionally, it can be queried for a number of different statistics (i.e., frequency of rental by title or classification, overdue rentals, inventory search by title, etc.).

The bar code system used by The Federated Group is menu driven by scanning a specific function on a menu card. Figure 3.6 is an example of a menu card similar to those used by The Federated Group and other videotape rental businesses. A sample procedure for checking out a videotape involves accessing the system, scanning the member's bar coded identification, scanning the appropriate function (in this case check out), then scanning the individual videotape's bar code, and scanning END to terminate the transaction. A hard copy of the transaction is printed on a rental agreement form for the member's signature.

In addition to their video rental operations, The Federated Group has been using the code 3 of 9 bar code for about two years for a number of point-of-sale and warehouse

SYSTEM	LOAN PERIODS	FUNCTIONS
ACKNOWLEDGE	LOAN PERIOD 1	CHECK OUT
PROCEED	LOAN PERIOD 2	RENEWAL
ACCESS	LOAN PERIOD 3	CHECK IN
REPORT	LOAN PERIOD 4	CLEAR CHANGES
OFF	LOAN PERIOD 5	REFERENCE

Figure 3.6 Sample Bar Code Menu Card

applications. They are expanding its use in the warehouse and will eventually go to a paperless system. The new system under development will allow the company to track all shipments to its stores. As delivery trucks are being loaded, the bar codes are read, and the receiving warehouse will be able to download a record of the shipment in place of a paper bill of lading. [Ref. 11:p. 28]

The hard dollar benefits of using a bar code system, specifically in their videotape rental operations, are not available. However, both The Federated Group and The Wherehouse emphatically profess that they could not compete in today's videotape rental market without it.

4. <u>California Judicial System</u>

The California judicial system consists of 227 separate trial courts that process 18 million new filings and 12 million dispositions annually. In the course of a year, these cases generate approximately 36 million different transactions. [Ref. 12:p. 42]

In 1983, the Judicial Council of California and the Administrative Office of the Courts (AOC) began studying various methods of collecting, compiling, analyzing, and reporting statistical data on cases in the state's criminal and civil courts. This statistical data was to be used to identify how many cases are in progress, where they are and where they're going, and how long they've been in the

system. With this information, the AOC could allocate resources more efficiently. [Ref. 12:p. 42]

Their study evaluated the most prominent technologies of automated data collection and entry. But, their choice had to meet definite constraints; it had to be fast, simple, and flexible enough to adapt to the existing procedures. They rejected the key entry because it was too slow and had a high error rate. Magnetic stripes lost out due to their high cost and their read-write capability was a potential security problem. OCR was slow, error-prone, and had a low first-read rate. Thus, the simplicity, accuracy, and efficiency of bar codes made them the preferred method. [Ref. 12:p. 42]

The next hurdle encountered was the selection of an acceptable bar code symbology. Since many courts used both alpha and numeric sequences, this limited the choices. Code 3 of 9 (the Department of Defense standard) was selected due to its wide range of alphanumeric flexibility and its proven success. [Ref. 12:pp. 42-43]

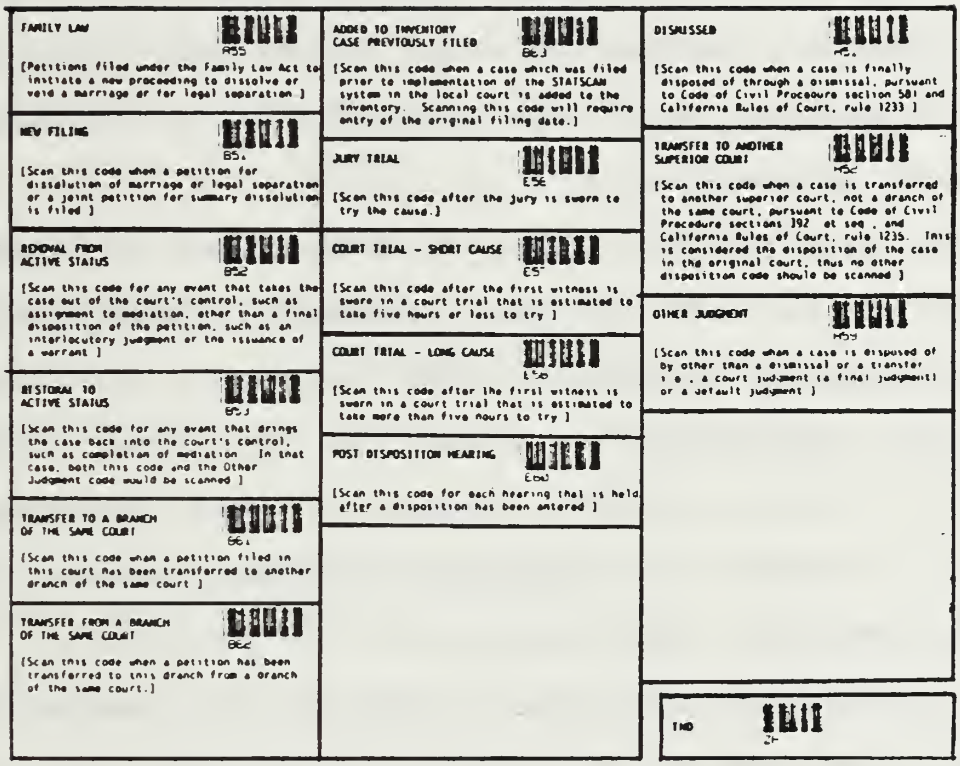
Having decided upon a method and symbol, the question of hardware and procedures had to be resolved. They did not want the California judicial system to make the same mistakes experienced by other states. A centralized host with numerous terminals connected to it had failed in similar applications. However, the Judicial Council of California opted to not only decentralize its 300 locations, but to

further decentralize their individual operators with portable terminals. The portable terminals have an internal clock-calendar that automatically time dates all transactions. [Ref. 12:p. 43]

A bar code data collection and entry system was installed in four courts in order to test its effectiveness. When a case was filed, a court clerk assigned a case number and attached a bar code label that corresponded to that court's numbering system. The clerk scans the case number, then a menu card of bar codes representing statistical information on the case. Figure 3.7 is an example of the Family Law Menu used by the Superior Court of California. [Ref. 12:p. 43]

After scanning the menu card, the clerk is prompted by the portable terminal to enter information such as case category, defendant identification number, event, etc. The system allows the clerk to assign the same case number to multiple criminal defendants with different defendant identification numbers. [Ref. 12:p. 46]

As cases move from filing to arraignment to pre-trial conferences to trial, the clerk scans the bar coded case jacket then the menu card to enter data on their progress. The data are transmitted daily into a microcomputer at the local court level then are compiled and transmitted weekly to a statewide host computer in Sacramento for analysis and statistical reports. [Ref. 12]



FAMILY LAW

A55

[Petitions filed under the Family Law Act to instiate a new proceeding to dissolve or void a marriage or for legal separation.]

NEW FILING

[Scan this code when a petition for dissolution of marriage or legal separation or a joint petition for summary dissolution is filed.]

REMOVAL FROM ACTIVE STATUS

B52

[Scan this code for any event that takes the case out of the court's control, such as assignment to mediation, other than a final disposition of the petition, such as an interlocutory judgment or the issuance of a warrant.]

RESTORAL TO ACTIVE STATUS

[Scan this code for any event that brings the case back into the court's control, such as completion of mediation. In that case, both this code and the Other Judgment code would be scanned.]

TRANSFER TO A BRANCH OF THE SAME COURT

[Scan this code when a petition filed in this court has been transferred to another branch of the same court.]

TRANSFER FROM A BRANCH OF THE SAME COURT

[Scan this code when a petition has been transferred to this branch from a branch of the same court.]

ADDED TO INVENTORY CASE PREVIOUSLY FILED

B63

[Scan this code when a case which was filed prior to implementation of the STATSCAN system in the local court is added to the inventory. Scanning this code will require entry of the original filing date.]

JURY TRIAL

E56

[Scan this code after the jury is sworn to try the cause.]

COURT TRIAL - SHORT CAUSE

[Scan this code after the first witness is sworn in a court trial that is estimated to take five hours or less to try.]

COURT TRIAL - LONG CAUSE

[Scan this code after the first witness is sworn in a court trial that is estimated to take more than five hours to try.]

POST DISPOSITION HEARING

[Scan this code for each hearing that is held after a disposition has been entered.]

DISMISSED

[Scan this code when a case is finally disposed of through a dismissal, pursuant to Code of Civil Procedure section 581 and California Rules of Court, rule 1233.]

TRANSFER TO ANOTHER SUPERIOR COURT

[Scan this code when a case is transferred to another superior court, not a branch of the same court, pursuant to Code of Civil Procedure sections 392 et seq., and California Rules of Court, rule 1235. This is considered the disposition of the case in the original court, thus no other disposition code should be scanned.]

OTHER JUDGMENT

[Scan this code when a case is disposed of by other than a dismissal or a transfer i.e., a court judgment (a final judgment) or a default judgment.]

END

Figure 3.7 Sample California Court System Menu Card [Ref. 12:p. 45]

As with any other test program, the system has had its bugs. For example, the "beep" commonly emitted when scanning bar codes, has been disruptive in the courtroom. As a result, the clerks, through the AOC, have requested that it be replaced with a flashing light that indicates a successful read. But the biggest problem was not bar code related, it has been with data communication links between sites. Once this problem has been solved, the California judicial system will be ready to begin full implementation of their bar code system.

One problem that failed to materialize was that of resistance from court clerks. Normally, resistance to change is expected because of human nature. The bar code system was overwhelmingly accepted by the court clerks. According to Jerry L. Short, manager of Court Consultative Services, the system improved their efficiency so much that the clerks loved it. [Ref. 12:p. 46]

Acceptance by the court clerks and the resoundingly successful test results outweighed the problems. The test yielded a 100 percent increase in the accuracy of reporting workload statistics and a 200 to 300 percent increase in efficiency. As a result, installation of the bar code system has begun in an additional 28 courts. [Ref. 12:p. 46]

Progress is being made on the communication problem, and when solved, installation will continue throughout the

court system. When fully operational, the California judicial system will shift from reacting to bottlenecks to pro-active planning. As future increases in categoric actions are identified in a particular jurisdiction, resources will be put in place to handle the workload. Accordingly, both costly delays and idle courts will be minimized or completely eliminated.

Although people in a paper-work environment have often failed to identify themselves as a production process, their files are nothing more than "work in progress." Fortunately the California judicial system has recognized this similarity and has undoubtedly selected bar codes as the present (as well as future) means of increasing productivity, timeliness, and accuracy without an increase in manpower.

5. <u>Louisiana State University</u>

In August 1985, Louisiana State University (LSU) in Baton Rouge installed a bar code based ticketing system to issue student football tickets. This culminated their search for a fast, inexpensive, and easily implementable system that would ensure legitimate students had the opportunity to attend home football games.

The University's enrollment includes approximately 29,000 full- and part-time students, but the LSU stadium only has 14,800 highly prized seats in a section designated exclusively for student use. Before the installation of the

bar code based ticketing system, anyone with a current LSU student identification card was permitted to enter the stadium. Since this system was subject to abuse, the student section was frequently filled with not only legitimate students, but a number of ineligible individuals. Since fire safety codes limited the maximum occupancy in the various sections of the stadium, students who showed up after the 14,800 seat student section had been closed were either denied admission or had to purchase a ticket in another section (if available). [Ref. 13:p. 50]

The new student ticketing system necessitated the issuance of a bar coded identification card that could be scanned and checked against a database before a student was allowed into the game. The university opted for an Academic Career Card that is issued for the duration of a student's enrollment. Each plastic student identification card is printed with a unique, bar coded twelve digit identification number. The first nine digits are the numerals in the student's social security number in reverse order. Since most social security numbers issued for Louisiana begin with 433 or 434, reversing the numerals reduced the number of iterations required during a binary search of the university's database. The last three characters consist of a student status digit; a card sequence number (first, second, etc.) to prevent lost or stolen IDs from being used; and a check number. [Ref. 13:pp. 50-52]

Hardware for the new system consists of twelve laser scanners connected to two IBM PC/AT microcomputers (six readers to each micro) for use by ticket takers at the stadium on game day. Additionally, slot readers connected to the university's mainframe are used at three campus locations in the ticketing process. [Ref. 13:p. 51]

From Monday through Wednesday, only full-time students are allowed to pick up their free ticket and purchase an additional guest ticket. Beginning Thursday, part-time students can buy tickets, and on Friday tickets are available to the public. The ticket seller runs the student's ID card through a slot reader that scans the bar code and searches the main database for status information from the student's record. This on-line process not only prevents those ineligible from receiving or purchasing tickets, it also advises the seller if the student has already bought tickets.

After the ticket windows have closed on Fridays, the information that was collected and stored during the week is processed at the computer center. Using software developed at LSU, a master file is built from the student database of everyone eligible to attend the upcoming game, whether or not they purchased a ticket. This file is downloaded to the IBM PC/ATs and placed in memory using virtual disk storage. [Ref. 13:pp. 51-52]

Two hours before kickoff time, twelve ticket takers use laser scanners connected to the micros to check student IDs. The bar code information is sent from the scanners to the microcomputers which search the database and send a message to the reader display. The system also uses an audible beep code to assist gate personnel as they check tickets. If the type ticket presented matches the student's status, he is allowed into the stadium.

With a uniform arrival rate and two hours to get almost 15,000 people into the student section of the stadium, each person would have about five seconds to pass through the gate. Unfortunately, the arrival rate is far from uniform. The majority of the students arrive just before game time; therefore, the scanning process and system response time must be considerably faster than five seconds per student. Even with all readers in constant use, the LSU bar code based system provides an average response time of 0.75 seconds. This allows an ID to be scanned and verified faster than a person can walk through the turnstile. [Ref. 13:p. 52]

Although football spurred the implementation of a bar code system at LSU, it was only the beginning. The university library recently installed an automated charging system that uses the bar coded information on the identification cards. In the near future, LSU plans to install a

bar code system in their food services department that will check IDs for cafeteria privileges.

As for hard benefits, they expect that the system will more than pay for itself by no longer replacing identification cards annually. Furthermore, all departments at LSU have benefited because of ready access to more current student information than ever before. Overall, LSU views bar coding as an extremely efficient, cost-effective way to help run the university. [Ref. 13:p. 52]

6. <u>Blue Cross and Blue Shield</u>

Blue Cross and Blue Shield of Virginia receives over 315,000 claim inquiries annually that must be individually researched and responded to in as short a time as possible. In October 1985, they installed a bar code based computer system to improve efficiency and customer service in processing claim inquiries from physicians, hospitals, individual policy holders, and internal Blue Cross departments. [Ref. 14:p. 22]

Before installing its automated system, the status and location of all inquiries were tracked in manual log books. Initially each inquiry was entered into a log, then routed to the appropriate department or individual for research and recommendations. Depending on the complexity of the inquiry, it might have to go through several specialized departments and could be handled by as many as ten different people. Tracking and attempting to manage the

more than 1200 daily written inquiries manually proved extremely time consuming and in many cases ineffective [Ref. 14:pp. 22-23].

Once an inquiry was being researched, it tended to get lost in the process until it was completed. Consequently, it was almost impossible to check on the status of an inquiry without physically searching all the possible locations. This was not only an unacceptable situation internally, but tended to deteriorate customer relations.

To solve this growing problem, Blue Cross installed thirteen terminals with bar code reading wands and a central computer. The individual terminals were located at key locations in the Research Department. Now, when an inquiry arrives, a preprinted bar code label is attached to it and some basic information about the inquiry is entered into the system along with the bar coded data. As the inquiry moves through the process, each department or individual handling it records the appropriate transaction (received, processed, transferred, etc.) along with the bar coded label data into a terminal. This information is recorded by the central computer and permits status and location queries on all documents from any terminal. [Ref. 14:p. 22]

The management of Blue Cross and Blue Shield of Virginia is thoroughly satisfied with the new system. Since its implementation, the average inquiry process time has

gone from thirty days to fourteen days, and the work-in-process (backlog) has been reduced from 20,000 to 6000 inquiries [Ref. 14:p. 23]. Figure 3.8 graphically presents this impressive increase in efficiency.

Some of the other major benefits of the bar code based tracking and management system include: The system automatically identifies duplicate inquiries, which comprise three to four percent of all inquiries and equates to about eight manhours saved by eliminating duplicate processing. Priority requests can be tracked and processed in 48 hours. Overdue documents are automatically identified at a preset time limit. The system provides a statistically valid database that not only aids in corporate reporting, but helps identify and solve possible processing bottlenecks. [Ref. 14:p. 23]

When Blue Cross and Blue Shield of Virginia decided to automate, they needed a system that could work with paper, not eliminate it. Bar code technology and the microcomputer were the answer and have allowed them to interface with and efficiently manage voluminous written inquiries.

7. <u>Private Sector Summary</u>

The six cases presented in this section illustrate the diversity of bar code applications within the private sector. The familiar stripes that initially gained notoriety and proved highly successful at the supermarket

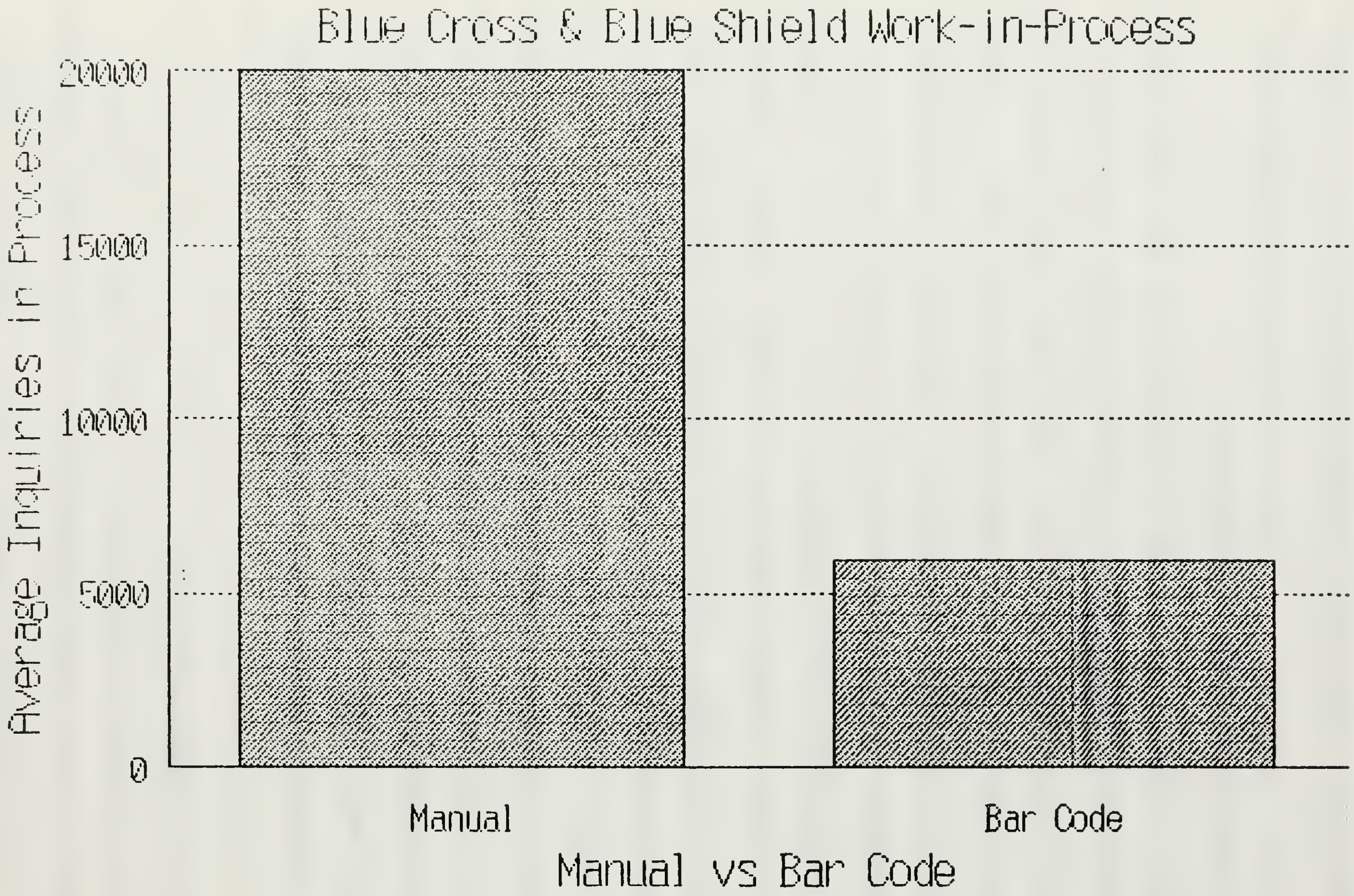


Figure 3.8 Blue Cross & Blue Shield Efficiency Increase with Bar Coding

checkout counter have proven equally successful in non-logistics applications. Inexpensive, widely accepted, and broadly applicable, bar codes are firmly implanted in literally hundreds of different automated data entry and management control systems. The private sector is reaping the benefits of increased efficiency and accuracy through their non-categorical use of existing bar code technology.

C. PUBLIC SECTOR

The Department of Defense is an acknowledged leader in the employment of bar coding for logistics applications. In fact, in the bar code industry, LOGMARS has become synonymous with bar coding. However, bar coding applications outside logistics within the DOD are virtually nonexistent. As the one exception, the United States Military Academy at West Point has installed bar code systems in its textbook issuance and accountability department and its garment tracking system.

Data from these two applications are presented and tend to complement the private sector cases. Additionally, four selected cases are presented that are more typical LOGMARS applications and are both complementary and contrasting to this study.

1. West Point Textbook Issue and Accountability

In April 1985, the United States Military Academy (USMA) at West Point completed installation of a bar code based system designed to improve efficiency in textbook

issue and accountability. Their system consists of eight portable bar code readers (PBCR) with laser scanners, two bar code label printers, and a microcomputer for data collection.

The system has been termed CADET, for Cadet Accountability Department Education Textbook. When textbooks are received, they are assigned a unique bar coded identification label which is entered into the database along with the quantity received. Cadets are also issued a bar coded identification number that they use for textbook issue. Primarily, the system was designed to facilitate the inventory of textbooks and to accurately charge cadets for textbooks issued.

According to the USMA, the system cost approximately $40,000, but will save an estimated $23,000 annually in reduced labor costs over the manual textbook issue program. In addition to the estimated cost savings, the new system is at least 50 percent more accurate. And, the speed of operation versus the manual method and increased accountability are not quantifiable. [Ref. 15:p. C-1]

Unlike the private sector, if there is any possible way, Government agencies attempt to quantify benefits. But regardless of quantifiable benefits, the United States Military Academy has clearly benefited from increased efficiency and accuracy through the implementation of bar coding.

2. Cadet Garment Tracking System

The United States Military Academy at West Point operates a cadet clothing factory that manufactures and issues the majority of cadet uniforms. During fiscal year 1986, they began installation of a bar code based system to track the manufacture, issue, and turn-in of all garments manufactured at the cadet clothing factory. [Ref. 15:p. C-2]

The system will use cloth bar coded labels attached to each garment. Additionally, the system will utilize two portable bar code readers equipped with laser scanners, a bar code label printer, and a microcomputer. A cadet's bar coded identification number will be used for direct credit or debit of garments issued or turned in.

Hard dollar benefits have not been estimated; however, the new system will use less manpower in a shorter timeframe to account for uniform issues and turn-ins. Additionally, the manager of the cadet clothing factory will be able to track daily movement of inventory as opposed to monthly physical inventories. Despite the fact that the USMA has not estimated hard dollar savings, the increase in accuracy and efficiency are undeniable.

3. Parts Automated Repairable Tracking System

In March 1985, Randolph Air Force Base, Texas, completed installation of a bar code based computer system designed to track repairable aircraft parts going through

scheduled inspection and maintenance. Positive control of repairable assets throughout the repair cycle is achieved with the new system by tracking the status and location of repair cycle assets at base level production control.

The system consists of 19 terminals connected to a central computer, 16 laser scanners and bar code readers, 2 bar code printers, and 3 dot matrix printers for hard copy documentation [Ref. 15:p. A-1].

When an aircraft is inducted into a scheduled inspection or maintenance cycle, the parts removed for repair are tagged with a bar coded label. The label, which identifies the part and the aircraft, is scanned and information regarding the inspection/maintenance cycle and scheduled completion date are entered into the computer. As each individual part moves through the repair cycle, the bar coded label is scanned and transaction data (i.e., received, transferred, completed, etc.) is entered into the database at each work center. Production control can readily identify the status and location of repairables throughout the repair cycle and assign appropriate priorities.

Hard dollar savings are estimated to be $90,000 annually. Included in this figure are a $60,000 reduction in inventory costs and the elimination of $30,000 for lost items, the incidence of which has dropped to zero since installing the new system. In addition to the quantifiable benefits, the new system has produced a manpower savings

through the reassignment of eight maintenance personnel from the production control section to sortie producing jobs. [Ref. 15:pp. A-1--A-1.1]

This system has proven highly successful and has been completely accepted by maintenance personnel since it not only makes their jobs easier, but more productive. Repairable parts are going through the cycle faster; as a result, aircraft going through the scheduled inspection and maintenance no longer have to wait for repairables. In fact, repair of parts are completed before the aircraft is available for reinstallation. These improvements in productivity are directly attributable to the bar code system and have exceeded all expectations.

4. Motor Pool Fuel Accountability

Although bulk petroleum oils and lubricants are listed as exceptions to LOGMARS, the use of a bar code system to account for fuel dispensed from transportation motor pools is an acceptable application. The motor pool at Fort McPherson, Georgia, served as the LOGMARS lead site for the implementation of a bar code based fuel accountability system.

Hardware for the system consists of two portable bar code readers for data collection and a modem for downloading the data to the base mainframe computer. Bar code labels are attached to vehicles for identification and to the fuel pumps in the motor pool to identify the types of fuel. When

a vehicle is service, both labels are scanned and the number of gallons are entered into the portable bar code reader on its keyboard. The data collected with the portable bar code readers is downloaded into the mainframe for processing.

Fuel has always been a highly pilferable item; therefore, the required accountability systems were often complex and extremely time consuming. This bar code system not only provides total accountability, but has increased accuracy and saved manpower by eliminating manual worksheets and keypunching requirements. Savings from tangible and intangible benefits are estimated to be $18,000 annually. [Ref. 15:pp. E-1--E-1.1]

5. <u>Bar Code Accountable Property System</u>

The Defense Logistics Agency (DLA) established two sites in fiscal year 1985 to test the Bar Code Accountable Property System (BARCAPS). The test sites were established at Defense Depot Ogden, Utah, and Defense Construction Supply Center, Ohio. This bar code inventory system was designed to enhance an established automated system known as BOSS (Base Operating Supply System).

The Base Operating Supply System utilized an IBM PC/XT into which manually collected inventory data were key entered. After the inventory had been entered into the micro, the data were uploaded into the facility's mainframe for processing and reconciliation. BARCAPS has provided an automated method of collecting inventory data on accountable

property through the use of bar coded labels attached to the property and portable bar code readers.

Each test site uses two portable bar code readers (PBCR) to scan the property labels. The inventory information, automatically collected when a label is scanned, is stored in the PBCR until it is downloaded to a micro previously used by the Base Operation Supply System. Then the data, as in BOSS, are uploaded to a host computer. However, a BARCAPS inventory reconciliation program automatically reconciles the data to a master file in the host computer. When the program has been run, inventoried items are categorized as reconciled, overages, or shortages. [Ref. 15:pp. O-2-O-2.1]

The system is estimated to save $100,000 annually in intangible benefits. It improves management and control for the life cycle of a particular item. Additionally, data collection and information processing are faster and inventories are more accurate. This increased efficiency and accuracy equate to a higher level of accountability and have all but eliminated the use of paper in property inventories. [Ref. 15:pp. O-2--O-2.1]

6. <u>Navy Ammunition Inventory</u>

This case provides an extensive look at the application of the LOGMARS program for the inventory of Navy ammunition at eight ordnance sites. In 1979, the Navy initially began their ammunitions study at the request of

the Joint Steering Group for Logistics Applications Of Automated Marking And Reading Symbols (LOGMARS). Following the completion of the LOGMARS study in 1981, Secretary of Defense Caspar Weinberger encouraged the armed services to implement bar coding wherever practical and economical. [Ref. 16:p. 4]

Before the application of bar codes, the Navy's ammunitions were marked with an identification tag that had the National Stock Number (NSN) and the produce name written on it. During an inventory, a team of two or three people read the tags and transcribed the information from these tags to a tally sheet, along with an actual count. The data were compared with hard-copies, reconciled, then entered into a computer and processed. [Ref. 16:p. 4]

This procedure was slow, labor intensive, and error prone. Information was misread from tags, transcribed incorrectly on tally sheets, and keypunched incorrectly. These opportunities for error are the lifeblood of the movement from manual data collection and entry to bar coding. [Ref. 16:p. 4]

With the bar code system, three labels are used. One identifies the item, a second its lot or serial number, and a third its location. The label identifying location is removed/replaced as a pallet or container is moved within a magazine. Additionally during an inventory, the identity of the individual conducting the inventory must be entered into

the system either by scanning a bar coded identification badge or by entering the individual's identification number into the system. [Ref. 16:p. 22]

Although teams are still used to inventory a magazine, each member is equipped with a portable bar code reader. Labels can be read in seconds with virtually no errors and are scanned in sequence: location, identification, and lot/serial number. When the inventory has been completed, the data are downloaded to a central computer. There the information is processed and compared to the Activity's Ammunition Master File (AAMF). If the data agree, the inventory is complete and the master file reflects the date. If, however, any data element in the two records differ, both the master file and the scanned data are printed for review and reconciliation. [Ref. 16:p. 22]

According to its users, the system is a complete success. Some of its benefits are tangible and immediate. Inventory errors have been significantly reduced, both in paperwork and physical count. Additionally, inventory data have been recorded quicker and with more accuracy. Other benefits are not as tangible, but just as significant. One of these is improved morale. As a result of bar coding, the people working at the weapons stations are no longer required to work with a flashlight and a pencil in order to inventory a magazine. [Ref. 16:p. 22]

Perhaps the most quantifiable benefit is the drastic reduction in the time required to complete an inventory. It has gone from 28 manhours under the old system to 2.5 manhours with the bar code system [Ref. 16:p. 22]. (Figure 3.9 is a graphic representation of this tremendous decrease in manhours.) The combined benefits equate to a reduction in operating costs; but the bottom line is better asset control and accountability.

Due to the success of the bar code system, steps were taken to export the capability to other facilities as well as to expand its capabilities at the eight test sites. The two current Navy ammunition programs are the Ordnance Management System (OMS) and the Fleet Optical Scanning Ammunition Marking System (FOSAMS). In addition to the inventory application, OMS plans include the use of bar codes in other functions (i.e., receipt, issue, segregation, production, etc.). [Ref. 16:p. 22]

7. Public Sector Summary

Despite the expanded bar code applications at the United States Military Academy, the Department of Defense bar code based systems are predominantly logistics oriented. Clearly, the current DOD applications are successful and yield both tangible and intangible benefits. Their somewhat obvious focus on implementing bar code systems for logistics applications should not be looked upon as tunnel vision. Perhaps it's a simple case of categorizing LOGMARS as

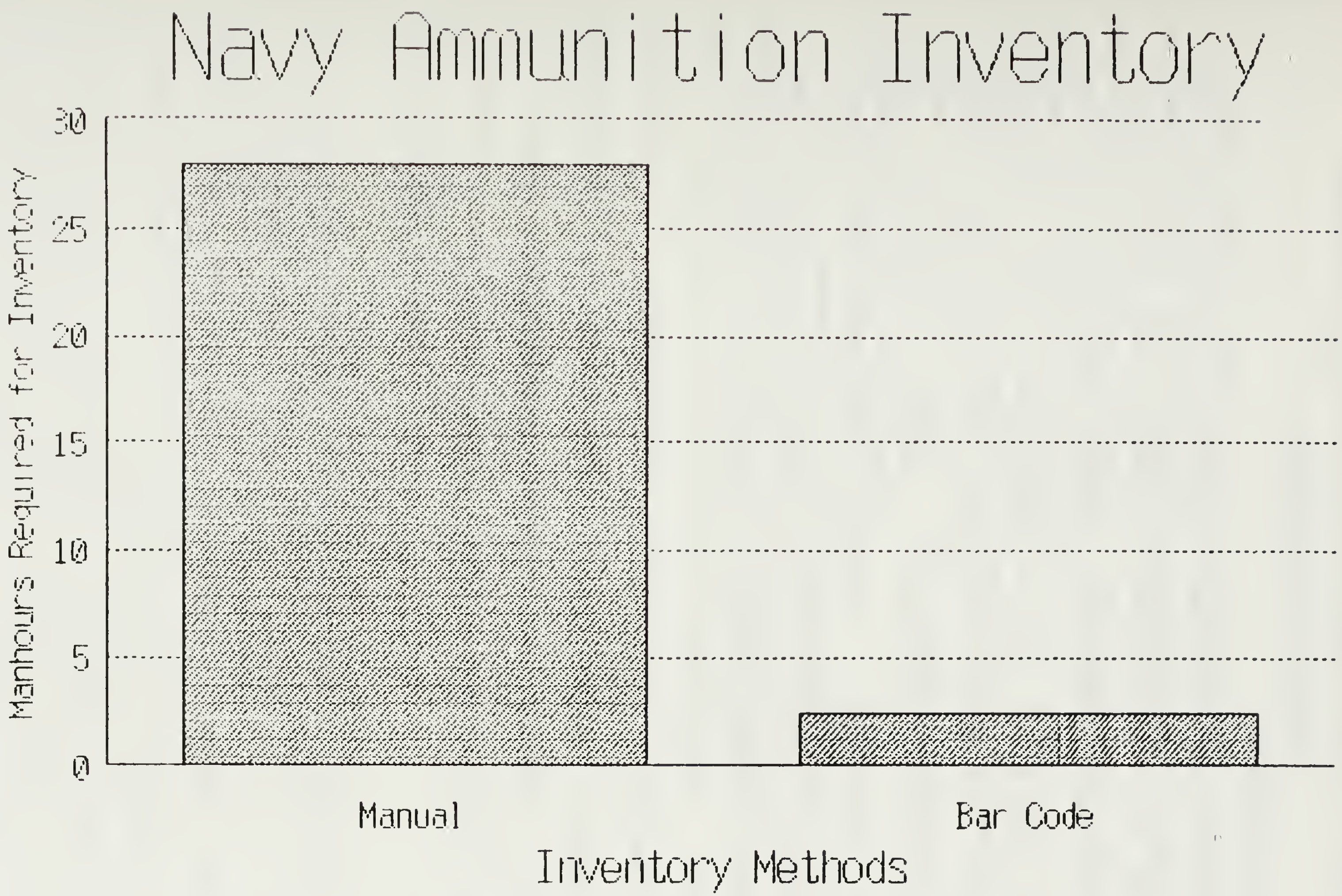


Figure 3.9 Navy Ammunition Inventory Manhour Reduction with Bar Code System

"logistics," and inadvertently overlooking the broad range of bar code uses beyond inventory-type control systems.

D. CONCLUDING REMARKS

This chapter has provided a quick look at the rapid growth enjoyed by the bar code industry today by presenting applications of bar codes in the private and public sectors. Although bar coding may not be beneficial in all automated data collection and entry situations, the bar code systems in the cases examined generated a variety of benefits, both tangible and intangible. Comments from users about their bar code systems varied, with one distinct exception; they were unanimous in never wanting to return to the "old" way.

IV. COMPARATIVE ANALYSIS

The private sector has unquestionably expanded the use of bar coding far beyond the supermarket checkout counter and mere inventory control. Drawing from these applications, the Department of Defense has everything to gain and nothing to lose by exploring the possibilities of using bar codes in similar areas. The highly successful LOGMARS program has room for growth.

Current Department of Defense administrative procedures suggest areas where the non-logistics applications of bar code technology are potentially beneficial. This chapter presents a comparative analysis of replacing manual procedures with a bar code system in two selected areas at the Naval Postgraduate School. The cases presented are similar in nature to private sector applications examined in the previous chapter.

A. NAVAL POSTGRADUATE SCHOOL ATTENDANCE MONITORING

Throughout the course of an academic year at the Naval Postgraduate School (NPS), a number of events are scheduled in addition to regular classes at which attendance is mandatory by students and/or staff. Included in these events are the Superintendent's Guest Lecture Series, specialized curriculum lectures, Naval community oriented lectures and

symposiums, security briefings, and special courses and seminars.

Current attendance monitoring procedures involve either the collection of a pre-printed attendance card or a "sign-up" sheet that are manually reconciled. For simplicity in terminology and procedural examples, the remainder of this case will only address the attendance cards and their associated utilization for NPS Superintendent's Guest Lectures.

When a student checks into his/her respective curricular office, a secretary types the student's name, rank, service number and section number on a NPS Superintendent's Guest Lecture Series Card (NPS form 12ND NPS 5512/3 <2/70>) for the Curricular Officer's signature. (Figure 4.1 is an example of this card and Figure 4.2 is an example of a prototype NPS bar coded card/label.) Prior to each Superintendent's Guest Lecture, the cards are stamped with the date of the event by a curricular office secretary, then issued to the students by their section leaders. On the day of the lecture, each Curricular Officer or Assistant Curricular Officer collects the cards at the entrance of the auditorium. Following the event, the cards are manually sorted by section, compared to a roster, and an absentee list is prepared. To say the least, this procedure is time-consuming, inefficient, and subject to considerable inaccuracy. [Ref. 17]

SEC. ML-54

NAME (LAST, FIRST, MIDDLE)	RANK
DOE, John J.	LCDR

is admitted to the scheduled lecture at King Hall at 1515 on

SIGNATURE (CURRICULAR OFFICER)	NO.
	123-45-6789

SUPERINTENDENT'S GUEST LECTURE SERIES 12ND NPS 5512/3 (2-70)

Figure 4.1 Current NPS Attendance Monitoring Card

000000399

NAVAL POST GRADUATE SCHOOL
MONTEREY, CALIFORNIA
ADMINISTRATIVE SCIENCES

DOE, John J. LCDR, USN
123-45-6789
Section #ML-54

Figure 4.2 Bar Coded NPS Attendance Monitoring Label/Card

The Naval Postgraduate School operates on the quarter system, and an academic year consists of four quarters of twelve weeks each. Eleven weeks of each quarter are reserved for classroom instruction and one week is designated for final examinations. Although all students cannot be "free" at the same time every week, due to classroom scheduling, a concerted effort is made to avoid scheduling classes between 1500 and 1700 on Tuesday afternoons, which is reserved for the Superintendent's Guest Lectures. Additionally, each curriculum schedules a weekly two hour block for special events. Since there are 44 instructional weeks in an academic year, this study will use the assumption that the average student will attend one special event per week or 44 annually.

At any one time, the average population at NPS is approximately 1800 students and 200 staff. It should be noted that several factors enter into the number of students that arrive or depart in a quarter. NPS has 11 different curricular departments and over 40 curricula that range in length from 3 to 36 months with an average length of approximately 18 months. Without going into further detail, 18 months will be used as a hard figure for a curriculum's duration in the remainder of this study. The other factors involved are extremely complex (i.e., the "needs" of the fleet, inter-service students, foreign students, etc.); therefore this study assumes 1200 students arrive annually.

Given the aforementioned data and assumptions, approximately 1763 manhours are expended annually to monitor attendance at special events using the card system. Table 4.1 presents a breakdown of the manhours required under the current system.

Through the use of current bar code technology and a database the manhours required for this task could be reduced by over 78 percent to an annual requirement of approximately 383 manhours. Table 4.2 provides a comparison of the manhours required with a bar code system.

What follows is a description of a test program that uses a bar code based attendance monitoring system. It is designed to use portable bar code readers for data collection and a microcomputer for processing. A Telxon PTC-701 portable bar code reader with a laser scanner was provided by the LOGMARS Project Office, Navy Fleet Material Support Office (FMSO), Mechanicsburg, Pennsylvania. It is programmed to read the Department of Defense standard, Code 39, bar boded labels. The LOGMARS Project Office also developed an attendance monitoring program for the Telxon called "NPS Attend," and the software for uploading the data collected to an IBM-PC.

The "NPS Attend" program has a date and time feature that are automatically maintained by an internal clock in the Telxon. However, the operator is prompted to accept or change these when the program is called up. Additionally,

TABLE 4.1

CURRENT NPS ATTENDANCE MONITORING SYSTEM MANHOURS

Activity	Time	Factors	Total MH
Type cards	1 min.	1200 S	20
Sign cards	15 sec.	1200 S	5
Date stamp cards	15 sec.	1800 S x 44 E	330
Issue cards	10 min.	60 M x 44 E	440
Collect cards	30 min.	11 C x 44 E	242
Sort, Review, Prepare absentee list, & Refile	1.5 hr.	11 C x 44 E	726
Total Manhours Required with Current System ---------			**1763**

TABLE 4.2

NPS BAR CODE ATTENDANCE MONITORING SYSTEM MANHOURS

Activity	Time	Factors	Total MH
Issue bar code label & database entry	1 min.	1200 S	20
Collect data	30 min.	11 C x 44 E	242
Upload data, Sort, & Print absentee list	15 min.	11 C x 44 E	121
Total Manhours Required with Bar Code System ---------			**383**

Notes: S = Students
E = Events
M = Sections
C = Curricular Departments

the program prompts the operator with "Class Title?" to enter a 16 character alphanumeric name for the data being collected. Once the class title has been entered and accepted, the program responds with "Student ID?" indicating that it is ready to collect data. In the "NPS Attend" program, the Telxon will scan, read, and store a nine digit numeric bar code in approximately four seconds. The data are stored in the Telxon's 32K memory until it is uploaded to a database in an IBM-PC (or equivalent).

Naval Postgraduate School Information Systems wrote the software for creating a database that is compatible with the "NPS Attend" program and that will process the bar code data. Pertinent information on all students and/or staff will be entered into a record in the database and will provide a variety of sorting capabilities. Table 4.3 is an example of the type and size of information that is entered into each record; it also includes a sample student record. [Ref. 17]

The bar code based attendance monitoring system would replace the Superintendent's Guest Lecture Series card with a bar coded label attached either to the student's military identification card or a separate card. When operational, the label would be bar coded with the student's social security number. For the test program, FMSO printed consecutively numbered nine digit labels. Figure 4.2 (previously

TABLE 4.3

NPS ATTENDANCE MONITORING DATABASE RECORD SAMPLE

Type	Size	Sample
SSN	9 digits--numeric	123456789
Name	20 digits--alpha	Doe, John J.
Curricular Dept.	2 digits--numeric	36
Section Number	4 digits--alphanumeric	ML54
Rank	2-4 digits--alpha	LCDR
Designator	4 digits--numeric	1310
Security Clnc.	4 digits--alpha	CONF
Service	2-4 digits--alpha	USNR

shown with Figure 4.1) is an example of the bar coded label provided by FMSO.

Under the bar code system, the bar coded label or card will be issued and their information entered into the database during the check in process. This is estimated to take about the same amount of time as typing the cards, currently in use. At a guest lecture, personnel from the curricular office will scan the label and the data is stored for later processing. Again, this data collection process with portable bar code readers is expected to require the amount of manhours as the current system. However, this is where the similarities end.

Once the data is collected, it will be uploaded to a personal computer for processing. This task is estimated to

require approximately 15 minutes per curricular department per event, or about 121 manhours annually as shown in Table 4.2 (previously introduced with Table 4.1). All of the other manual tasks required by the current system are eliminated with the bar code system. A comparison of the data in Tables 4.1 and 4.2 reveals that a bar code based attendance monitoring system will save 1380 manhours annually.

Up to this point, the benefits of automating the Naval Postgraduate School attendance monitoring system with bar codes have been expressed only in terms of manhour savings; however, there are those who advocate the old adage that "time is money" and need or want a dollar figure to measure the benefits. Tables 4.4 and 4.5 apply dollar figures to the manhours developed in Tables 4.1 and 4.2. For conservative reasons, the annual manhours required to perform a specific task are multiplied by the composite hourly rate of the lowest pay grade level, civilian or military, performing a task [Ref. 17]. Comparing the data in Tables 4.4 and 4.5 indicate a savings of $21,404.95 annually.

Skepticism might intervene and dictate the exclusion of military labor. Tables 4.6 and 4.7 present an analysis of the civilian manhours and their respective expenses required under the two systems. A comparison of the totals reveals a savings of $7,124.70 annually; but perhaps more important is the annual reduction of 935 manhours.

TABLE 4.4

CURRENT NPS ATTENDANCE MONITORING SYSTEM EXPENSES

Activity	MH	Factors	Total $
Type cards	20	GS-4 @ $ 7.62	$ 152.40
Sign cards	5	O-5 @ $38.29	$ 191.45
Date stamp cards	330	GS-4 @ $ 7.62	$ 2,514.60
Issue cards	440	O-4 @ $32.02	$14,088.80
Collect cards	242	O-1 @ $16.67	$ 4,034.14
Sort, Review, Prepare absentee list, & Refile	726	GS-4 @ $ 7.62	$ 5,532.12
Total Manhour Expense with Current System ------			**$26,513.51**

TABLE 4.5

NPS BAR CODE ATTENDANCE MONITORING SYSTEM EXPENSES

Activity	MH	Factors	Total $
Issue bar code label & database entry	20	GS-4 @ $ 7.62	$ 152.40
Collect data	242	O-1 @ $16.67	$ 4,034.14
Upload data, Sort, & Print absentee list	121	GS-4 @ $ 7.62	$ 922.02
Total Manhour Expense with Bar Code System -----			**$ 5,108.56**

NOTES: The factors in Tables 4.4 and 4.5 are the lowest pay grade performing a given activity and their composite hourly rate.

TABLE 4.6

CIVILIAN MANHOURS & EXPENSES UNDER CURRENT SYSTEM

Activity	MH	Factors	Total $
Type cards	20	GS-4 @ $ 7.62	$ 152.40
Date stamp cards	330	GS-4 @ $ 7.62	$ 2,514.60
Sort, Review, Prepare absentee list, & Refile	726	GS-4 @ $ 7.62	$ 5,532.12
TOTALS:	**1076 Manhours**	**------------**	**$ 8,199.12**

TABLE 4.7

CIVILIAN MANHOURS & EXPENSES UNDER BAR CODE SYSTEM

Activity	MH	Factors	Total $
Issue bar code label & database entry	20	GS-4 @ $ 7.62	$ 152.40
Upload data, Sort, & Print absentee list	121	GS-4 @ $ 7.62	$ 922.02
TOTALS:	**141 Manhours**	**------------**	**$ 1,074.42**

NOTES: The factors in Tables 4.6 and 4.7 are the lowest pay grade performing a given activity and their composite hourly rate.

Both the dollar savings and manhour reductions may appear as tangible, measurable benefits; however, an actual reduction in personnel, as the result of implementing a bar coded attendance monitoring system, is unlikely. Nevertheless, the reduction in manhours, whether tangible or intangible, is real and beneficial. The manhours currently expended and not required with an automated system could be used for other tasks and possibly eliminate a future need to hire additional personnel.

Although the implementation of a bar coded attendance monitoring system might be viewed by some as a "policing" action, others look upon the current card system as "high schoolish" [Ref. 17]. Regardless of personal opinion, an automated attendance monitoring system will be not only more efficient, but more accurate. Additionally, expanding this application to other areas at the Naval Postgraduate School and increasing its benefits are virtually unlimited. The final section of this chapter includes an example of potential applications of this system that would require only minor modifications/additions and the next chapter includes recommendations for further research.

B. NAVAL POSTGRADUATE SCHOOL BACHELOR QUARTERS

The Bachelor Quarters (BQ) at the Naval Postgraduate School maintains a total of 219 rooms, 182 for officers and 37 for enlisted personnel. The NPS BQ Officer is responsible for administering the daily operations of the bachelor

quarters, which includes providing furniture for all of the rooms. The furnishings are considered minor property and must be physically inventoried and the inventory reconciled annually. Additionally, the rooms are supposed to be inventoried whenever a permanent resident checks in or out. [Ref. 18]

This is an example of how an inventory control system automated with bar codes can not only improve the efficiency of the NPS Bachelor Quarters annual minor property inventory, but also its accuracy. Improving efficiency equates to reducing the manhours required to perform a specific task; thereby, allowing those saved manhours to be used more effectively. Clearly, this proposed application is closely related to current LOGMARS procedures; and in fact, is similar to the Navy Ammunition Inventory Case presented in the previous chapter.

The current procedures employed by the NPS BQ involve a physical count of all items in a room and manually recording the respective "NAVPGSCOL UPH PSE #" (Naval Postgraduate School, Unaccompanied Personnel Housing, Personnel Support Equipment Number) on an inventory sheet. Figure 4.3 is representative of the inventory sheet currently used. Once a room has been inventoried, it is manually reconciled against a master inventory.

Both processes are labor intensive, time consuming, and error prone. Normally, an inventory team, consisting of the

BACHELOR QUARTERS OFFICE
NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943

PSE INVENTORY

BLDG. NO. ______ ROOM NO. ______

ITEM	ON HAND	PSE NO.
Bed, Couch	______	______
Bed, Rollaway	______	______
Bed, Single	______	______
Bookcase, Large	______	______
Bookcase, Small	______	______
Bullentin Board	______	______
Chair, Easy	______	______
Chair, Desk	______	______
Chest of Drawer	______	______
Desk, Study (Single)	______	______
Desk, Study (Tiered)	______	______
Footrest	______	______
Lamp, Desk	______	______
Lamp, Floor	______	______
Lamp, Table	______	______
Mirror, Wall	______	______
Pictures	______	______
Recliner	______	______
Refrigerator	______	______
Sofa, Upholstered	______	______
Table, Coffee	______	______
Table, End	______	______
Table, Night	______	______
Waste Basket, Large	______	______
Waste Basket, Small	______	______

OTHERS:

______	______	______
______	______	______
______	______	______

COMMENTS/REMARKS: ______________________________

____

____

______________ Date: ______ ______________ Date: ______
(Building Petty Officer) (BQ Officer)

Figure 4.3 NPS Bachelor Quarters Inventory Sheet

Assistant Bachelor Quarters Officer, an O-2, and a Building Petty Officer, an E-4, conducts the physical inventory. During the inventory, both team members sight each item; and the Building Petty Officer reads the corresponding identification number, while the Assistant BQ Officer records it. Then, either the BQ Officer or the Assistant BQ Officer reconciles the room inventory with the master inventory. If an error is discovered, the first step is to reinventory the room in question. After the second inventory, if the error still has not been reconciled and the first and second inventories agree, then a physical search is conducted for the property in question. Needless to say this is a very time consuming and often frustrating process. [Ref. 18]

The Bachelor Quarters master inventory accounts for over 5000 individual items and each room is furnished with an average of 22 items. The current inventory process revealed that it takes the two man team a minimum of 30 minutes to identify, count, and record the furnishings in one room. This equates to one manhour per room for the physical inventory alone. However, it is more difficult to place a hard figure on the reconciliation process. Currently, it takes between two and four hours to sift through the stack of pages in the master inventory and reconcile just one room. This time is affected by the number of items in a given room, as well as the number of rooms previously reconciled. Because it is not absolutely scientific, the remainder of

this study will use the lowest time, two hours, as the average time required to manually reconcile a single room with the master inventory. [Ref. 18]

Thus, it requires a minimum of 657 manhours just to conduct and reconcile the required annual inventory, without regard to the inventories when permanent residents check in or out. The remainder of this study will address only the annual inventory; however, the assumption can be made that any additional inventory and reconciliation requirements will use approximately the same manhours per room. Table 4.8 presents a breakdown of the hours required for an annual inventory of the NPS Bachelor Quarters and its subsequent reconciliation with the master inventory. Table 4.9 presents a similar analysis using a bar code system, and will be referred to later for a comparison of the two systems.

It should be noted that the times in Table 4.8 are only for the physical inventory and reconciliation. They do not include the time required to identify, record, and reconcile those items that have met or exceeded their service life and should be withdrawn from service; or, those items that require replacement due to wear and tear. Additionally, it is extremely time consuming to manually prepare a new master inventory, even after it has been reconciled. Since neither an accurate measure, nor a rough estimate, of these times

TABLE 4.8

CURRENT NPS BACHELOR QUARTERS INVENTORY MANHOURS

Activity	Time	Factors	Total MH
Sight, Identify, & Record items	30 min.	219 R x 2 P	219
Reconcile Inventory	2 hr	219 R	438
Identify replacement requirements	Unknown	Unknown	--
Update/Prepare New Master Inventory	Unknown	Unknown	--
Total Manhours Required with Current System ---------			**657**

TABLE 4.9

BAR CODED NPS BACHELOR QUARTERS INVENTORY MANHOURS

Activity	Time	Factors	Total MH
Scan bar coded label & collect data	10 min.	219 R x 1 P	36.50
Upload data, Sort, & Reconcile Inventory	15 min.	219 R**	54.75
Identify replacement requirements	Included in 2nd Activity		--
Update/Prepare New Master Inventory	Included in 2nd Activity		--
Total Manhours Required with Bar Code System --------			**91.25**

NOTES: R = Rooms
P = Personnel
**This factor assumes a separate data upload, sort, etc., for each individual room, which in reality would include several rooms without a time increase.

are available for the current system; they are both listed as unknown and no attempts have been made to quantify them.

The Naval Postgraduate School Bachelor Quarters recently implemented a computerized control system for reservations and room assignments, utilizing a MacIntosh PC. Although it has been in service for only a short period of time, they have expressed complete satisfaction with it and foresee this system as an effective means of improving their efficiency and accuracy. As time permits, they plan to establish a minor property database for the bachelor quarters' inventory. Hopefully, this will be used with a bar coded system; but in the worst case, could be used with a manual inventory that is key entered into the database.

The proposed system will utilize bar coded labels attached to each item that identify it by both its type (or nomenclature) and a unique identification number. During an inventory, the label will be scanned with a portable bar code reader programmed to identify a specific room location. Once the inventory has been completed, it will be uploaded to a personal computer for processing with an established database.

The Telxon portable bar code reader with a laser scanner, as described for use in the NPS Attendance Monitoring System, is ideal for this application. It can be programmed specifically for use by the NPS Bachelor Quarters' inventory procedures. The program, such as "NPS BQ

Inventory," would prompt the operator to enter a specific room number (similar to "Class Title?" in the "NPS Attend" program). Then, the operator would scan the bar coded labels on the furnishings in a room, which are recorded in the Telxon memory. Unlike the "NPS Attend" program, which provides for only one event ("Class Title"), before the data is uploaded; the inventory program should allow for scanning and collecting data with multiple titles before uploading. This would permit inventorying a number of individual rooms without stopping to upload the data.

The database in the NPS Bachelor Quarters' inventory should consist (at minimum) of the following items: Nomenclature (type), Identification Number, Service Life, Condition, and Location (Room Number of Storage). This would provide for a number of sorting capabilities, and facilitate the preparation of reports. Additionally, the master inventory would be perpetually updated.

Simulated inventory tests using portable bar code readers and laser scanners proved that the average BQ room can be inventoried in ten minutes or less. Additionally, this data can be uploaded, sorted, and reconciled with a database and a new inventory sent to the printer in less than 15 minutes. Table 4.9 (previously introduced with Table 4.8) presents an analysis of the manhours required to inventory the NPS Bachelor Quarters. A comparison of Tables

4.8 and 4.9 reveals that the bar coded inventory system will save at least 565.25 manhours annually.

This 565 plus manhour savings does not include the undetermined amount of time required to identify the furnishings that need/require replacement or to update and prepare a new master inventory, all of which are automatically identified and updated with a bar code based system.

As with the attendance monitoring system, some may need the manhours saved with a BQ automated inventory system to be put into dollar values. Tables 4.10 and 4.11 present a comparison of the manhour expenses required under the current NPS Bachelor Quarters inventory system and a bar code based system, respectively. The manhours required to complete a given activity are multiplied by the composite hourly rate of the lowest pay grade performing it. One exception exists, in which an inventory team is used for the physical inventory under the current system. In this case, the average composite hourly rate is used. As previously noted in Table 4.9, a "worst case" scenario, assuming that data is uploaded and processed separately for each room, is used in the bar code system calculations. During normal operations, several rooms would be inventoried prior to uploading the data for processing without a significant increase in the time required over that for a single room.

A comparison of Tables 4.10 and 4.11 reveals an annual savings of $11,626.16 with the implementation of the bar

TABLE 4.10

CURRENT NPS BACHELOR QUARTERS INVENTORY EXPENSES

Activity	MH	Factors	Total $
Sight, Identify, & Record items	219	* @ $18.25	$ 3,996.75
Reconcile Inventory	438	O-2 @ $21.35	$ 9,351.30
Identify replacement requirements	UNK	O-2 @ $21.35	$ --
Update/Prepare New Master Inventory	UNK	O-2 @ $21.35	$ --
Total Manhour Expense with Current System ------			**$13,348.05**

TABLE 4.11

BAR CODE NPS BACHELOR QUARTERS INVENTORY EXPENSES

Activity	MH	Factors	Total $
Scan bar coded label & collect data	36.50	E-4 @ $15.15	$ 552.98
Upload data, Sort, & Reconcile Inventory	54.75**	O-2 @ $21.35	$ 1,168.91
Identify replacement requirements	Included in 2nd Activity		$ 0.00
Update/Prepare New Master Inventory	Included in 2nd Activity		$ 0.00
Total Manhour Expense with Bar Code System -----			**$ 1,721.89**

NOTES: The factors in Tables 4.10 and 4.11 are the lowest pay grade performing a given activity and their composite hourly rate.

* = Average composite hourly rate of O-2 and E-4.

** = Based on separate transactions for each room; normally, transactions include several rooms, which reduce manhours.

code system. Both the manhour reductions and dollar savings appear as real benefits. In actuality, neither the budget nor the manpower authorization are expected to be affected by the savings. However, the manhours saved would be available for more effective use.

In addition to the measurable benefits presented, the unknown manhours required to identify replacement requirements and to update and prepare a new master inventory are eliminated with the bar code system. The accurate and timely data available will be extremely useful in the budget process, both in definition and preparation of the five-year budget. Finally, the bar code based inventory system would avail itself to a variety of extended applications. An example of possible extensions of this system and remarks concerning compatibility with their current automation efforts are included in the next section of this chapter.

C. SYSTEM EXTENSIONS AND REMARKS

With the implementation of any new system, particularly an automated data control and management system, one must always look for additional applications in order to get the most mileage out of the system. The following areas are examples of potential extensions of the two systems presented; however, they are by no means intended to be all inclusive.

1. Influenza Immunization

Annually, all active duty U.S. military personnel are required to be immunized against influenza. The Naval Medical Admin Unit at the Presidio of Monterey Health Clinic is responsible for administering the immunizations to personnel at the Naval Postgraduate School. Every year in the fall, they bring a team to NPS and give the immunizations on two consecutive days. A record of those who receive the shots is kept on "sign-up" sheets which are later reconciled and entered into individual medical records.

The bar code based NPS Attendance Monitoring System is readily adaptable to this application. Although the actual immunization process cannot be shortened with the use of bar codes, the manhours required for reconciling the "sign-up" sheets and entering the data in the appropriate medical record can be significantly reduced. The current procedures require three corpsmen about three days to sort through the sign-up sheets and make the entries in the health records. With a computer printout sorted by the last four digits of an individual's social security number (the filing method for health records), the time required to make the entries could be reduced to about one third.

The Telxon portable bar code readers with the "NPS Attend" program could be used for this application without modifications. Instead of entering a class title when

prompted by the program, an appropriate title would be entered for this event. Individual identification labels/cards would be scanned when a member was immunized and the data stored for later processing. After the immunization process had been completed, the data would be uploaded into a centralized database, sorted by the last four SSN digits, and a compliance roster printed. The Naval Medical Admin Unit would use this roster to make the appropriate entries in individual medical records. Additionally, an exception roster could be printed and used to notify those who still needed immunization.

Although this is a once a year process and probably would not warrant the implementation of a bar code system for it alone, it can easily piggyback on an established system. And, with this capability, the Naval Medical Admin Unit would undoubtedly develop additional applications for the system.

2. Cleaning Equipment Inventory

In addition to the furnishings for the bachelor quarters' rooms, the NPS Bachelor Quarters maintains a substantial amount of cleaning equipment. A logical extension of the bar code based inventory system would be an inventory control and status system for the cleaning equipment.

Using a separate database with records similar to those for the Personnel Support Equipment (PSE), an

automated system for the cleaning equipment inventory could share the hardware used for the PSE inventory. Not only could the system track the inventory, but it could provide a variety of status reports (i.e., preventative maintenance schedule, service life, etc.). If a particular piece of equipment was assigned to a specific location or individual, this could also be tracked.

Some items in the cleaning equipment inventory are considered highly pilferable. Even though a bar code system, itself, cannot prevent theft, it can and does create an atmosphere that discourages it. This is not meant to imply that the NPS Bachelor Quarters has either dishonest employees or residents, but occasionally these conditions exist in any organization. The bar code system would tend to dissuade those who might otherwise be tempted to take an item.

This is only one of many inventory control situations where an in-place bar code based system could be expanded and benefits increased with shared hardware.

3. Remarks

The total manhour and dollar savings that are reportedly realized with the implementation of a bar code based control system are contingent upon the unit of measure. In the case of the NPS Attendance Monitoring System and the NPS Bachelor Quarters Inventory Management System, if both military and civilian labor are included, the total

manhour reduction and their corresponding dollar value equate to 1945.75 manhours and $33,031.11 annually. A summary of the reduction in manhours and their respective expenses for the two NPS areas examined is presented in Table 4.12.

TABLE 4.12

MANHOUR AND DOLLAR SAVINGS WITH NPS BAR CODE SYSTEMS

Bar Code Application	Manhour Reduction	Dollars Saved
NPS Attendance Monitoring (Military and Civilian)	1380	$21,404.95
NPS Attendance Monitoring (Civilian only)	935	$ 7,124.70
NPS Bachelor Quarters Inventory	565.75	$11,626.16

The Naval Postgraduate School has an extensive inventory of computer support, form the mainframe in the computer center to an array of personal computers throughout the campus. Out of the concept of automation arises the question of compatibility. A case in point from this study is the test program developed for the NPS Attendance Monitoring System and the subsequent application to the NPS Bachelor Quarters Inventory System.

Although the "NPS Attend" program was designed for use with an IBM-PC database, with the proper software, bar coded data can be used with virtually any computer database. Since the NPS Bachelor Quarters have implemented a

reservation and room assignment control system utilizing MacIntosh personal computers, it is reasonable to assume that they will continue to use them and that all future automation should be compatible. Future compatibility is easily obtainable since the portable bar code reader simply collects the data without regard to the system to which it will be uploaded. A specific software program provides for uploading to a database and interfacing with the computer.

The final remarks refer to the costs of installing bar code equipment, which have been notably missing throughout this study. The costs of installing and maintaining a bar code based automated data collection and control system have not been overlooked; simply, no attempt has been made to enumerate them because of the difficulty involved in identifying them.

The course of this study has been focused upon a comparative analysis of bar code applications in the private and public sectors and their potential applications at the Naval Postgraduate School, as well as similar Department of Defense activities. With appropriate research in that area, the cost of a system can be determined along with its reported benefits.

This in no way detracts from the validity of this study or the undeniable benefits to be gained from bar coding. It merely serves to reinforce the need for

additional research in the area of cost/benefit analysis as recommended in the next chapter.

V. <u>CONCLUSIONS AND RECOMMENDATIONS</u>

Bar codes, once considered as only a future concept of an obscure method for instruments to read labels, are now firmly entrenched in American business society. Their familiar stripes, that initially enjoyed success at the supermarket checkout counter, are no longer reserved just for point-of-sale operations. As the least expensive, most broadly applicable, and most widely accepted technique for automated data entry, this study found that bar codes are firmly implanted in the management control systems of <u>both</u> the private and public sectors. Literally hundreds of diverse bar code based systems have been successfully implemented in order to reap its benefits of increased efficiency and accuracy.

The remainder of this chapter is organized to present a synopsis of bar codes and their future, conclusions regarding the considerations and decisions required before implementing a bar code system, recommendations for future research, and concluding remarks.

A. BAR CODES AND THEIR FUTURE

With present technology, bar codes are the only method of printing the bit-streams of ones and zeros which are the basis for the internal logic of all digital computers [Ref. 1:p. 1]. But by themselves, bar codes are nothing more than

labels that identify the people, items, processes, decisions, documents, events, or responses to which they are assigned.

When used in an automated data control system, bar codes communicate directly with computers through their printed machine language. They can transfer data for later processing or they can incite an immediate response to the data. Bar codes function as a highly accurate, flexible, and inexpensive communications link between man and machine.

Manually key entering data into a system is hardly comparable to a bar code entry method. A trained data entry clerk can key enter data at a rate of approximately 120 characters per minute with an approximate error rate of 1 in 300. Bar coded data can be entered at a rate of approximately 350 to 700 characters per minute with a substitution error rate of 1 in 3 million. [Ref. 19:pp. 6-7]

Despite its resounding success, there are those who view bar coding as a dying technology and think that something will come along to replace it. Of course, this is where the old adage of "missing the boat" may come into play since most industry experts consider the concept of bar codes as basic and that it is here to stay. In fact, it has been said that there are those who are using bar codes, and those who will.

Today, both Texas Instruments and Western Publishing bar code talking books for children and Casio bar codes music

programs. In the future, the German television industry plans to bar code their TV Guide with a message to date and characterize every program. The bar coded listing is designed for use in programming video recorders and will identify each program along with its station and month, day, and time of broadcast. Along these same lines, a bar coded telephone directory used with a scanner equipped telephone would significantly reduce the wrong-number rate.

Hewlett-Packard currently bar codes some of their computer programs. And in the future, software writers can look forward to a reduction in the tedious key entry process, when word-processors automatically print programs both in their familiar form and in their bar coded equivalent.

In addition to the continuously expanding utilization of bar code technology, its printing and reading technologies are also advancing. Allied Technologies recently introduced a bar code reader that not only reads the code, but also the reflectivity of a Polymer based label next to the code. This special label changes with not only chronological age, but also with the temperature to which a product has been exposed.

Advanced bar code technology of this nature is especially applicable to perishable products where both time and temperature affect their marketability. Additionally, this technology can be applied to temperature sensitive

production processes, such as the sterilization of food and medical products, where errors cannot be tolerated. This type bar code system can report the condition of a product as acceptable or unacceptable. And, even in the unlikely event that an inferior product bypasses the quality control of a manufacturer, the special labeling would readily identify it as unsafe for consumption or use to the ultimate user.

Bar coding definitely has a future! Those who regard it as obsolete, are just waiting for the pot of gold at the end of the rainbow. Certainly, future technology will undoubtedly develop a new system of automated data entry that will surpass bar coding, but this development is no more likely in the near future than the replacement of the computer itself.

B. IMPLEMENTING A BAR CODE SYSTEM

An original goal of this research was to find a hard and fast formula for implementing a bar code based automatic data control system. Such a formula would specify that if a situation or organization "fit" the criteria, then the system should be installed. Completion of the research verified that no single set of rules exists that can be applied to all situations and yield the correct decision.

However, this study did reveal that deciding whether or not to implement a bar code based system is really no different from any other management decision. This decision

process can be simplified and broken down into the following four basic steps:

- First, define the problem.
- Next, determine the goals to be achieved.
- Then, select the course of action.
- Finally, implement the plan.

These four steps seem simple enough, but there may be a little more to it. An up and coming manager of any organization may think that he can readily identify his situation with the first three steps; then he hears that little voice saying, "Do it. Do it. Do it!" But, the manager may have been overwhelmed by the success of others without completely considering his situation. Just because bar codes have proven successful in other situations does not mean that they are uniformly adaptable.

The first two steps are relatively straightforward and are almost always complementary. In the case of considering a data control system, the problem may be defined as a need to collect data efficiently and accurately. While the goals may include no increase and ideally a reduction in manhours, and/or a need for statistical data such as efficiency reports, time and attendance reports, work-in-process tracking and status, inventory reports, etc.

Perhaps the most important and consequently the most difficult step is selecting the proper course of action. Clearly, this study advocates the implementation of bar code

technology into a data control system because of the benefits previously identified. But this is not done blindly. Because a bar code label can be read faster and with more accuracy than manual entry of the same data, one would expect the course of action decision to favor bar coding. However, the decision must not be made by isolating the method of data entry from the entire control system.

The system as a whole must be examined from a broad perspective, and of prime importance for the implementation of any automated control system is the database. The decision maker must ask himself if a database exists for his application. If it does, then he must consider hardware and software compatibility when selecting the bar code equipment (or other data entry method). If it does not, then he must consider the time and resources required to build the database. It goes without saying that in most cases automating an existing system is easier and less costly than installing an entirely new one.

When a manager is weighing the alternatives, he should review his goals not only to ensure that the systems under consideration will achieve them; but also to examine its additional capabilities, future requirements, and potential extended applications of the system. Throughout the process and particularly when the decision for the course of action is imminent, similar outside applications should be looked at very closely. Finally, the selection of a course of

action should carefully consider the method of implementation. All too often, outside expertise and experience are overlooked in lieu of using in-house personnel. Although the do-it-yourself method may prove entirely satisfactory, it can cause delays which negate any anticipated savings and in some cases prove more costly.

After the first three steps have been completed, all that remains is implementing the system. The primary consideration here is to "do it" and not to get bogged down in waiting for something better to come along or attempting to implement "the perfect" system.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

Most research efforts develop more questions than are answered. This study is no different. The recommendations presented in this section are by no means all inclusive; but represent areas where additional research is both warranted and should prove beneficial.

1. Computer Technology, Support and Technical Factors

The Naval Postgraduate School mainframe computer is capable of assimilating massive amounts of data, and additionally, there is an extensive array of personal computers at NPS. The Department of Defense as well as NPS could benefit from the development of database programs and "generic" software compatible with bar code applications.

2. <u>Dudley Knox Library</u>

The Dudley Knox Library at the Naval Postgraduate School currently uses a "card" based charging system. This study should include an analysis of a bar code based charging system that compares the using the NPS mainframe computer with a back-up system to a stand-alone system. It also should consider using an identification card/label which would be universal to other NPS applications.

3. <u>Support and Tenant Activities</u>

This study could identify applications of existing or new bar code systems that may be beneficial to the various support and tenant activities at NPS. Some of these include: Recreational Services, Educational Media Department (EMD), Defense Resources Management Education Center (DRMEC), Aviation Safety School, and Practical Comptrollership Course (PCC).

4. <u>Copy Machine Utilization</u>

This recommendation would involve a feasibility study of using a bar code system to monitor the utilization of NPS copy machines. Its benefits might include a maximum authorization and charging system.

5. <u>Funding</u>

The LOGMARS Program occasionally provides funding for bar code equipment for lead sites and their extensions. Test programs at the Naval Postgraduate School may be available for special funds without an impact on its budget.

6. Bar Coded ID Cards and Vehicle Decals

This area could involve a test program applicable throughout the Department of Defense. All military identification cards are numbered and could be bar coded with that number. The potential applications are limited only by the scope of the study. Additionally, bar coded vehicle decals are potentially beneficial. Although both areas would probably require a practical test, the Naval Postgraduate School may well be the best testing grounds.

D. CONCLUDING REMARKS

When I initially volunteered for and began this study, I only knew that supermarkets and the commissary at Fort Ord, California, used bar codes to expedite the checkout process. And to me, LOGMARS was just another military acronym. Little did I know that these unpresumptuous stripes called bar codes may well hold the future of management control systems through their accurate, yet inexpensive method of automated data entry.

Just as the printed page is the standard of communication between human minds, bar codes are the standard of communication between man and machine.

Thus far with bar coding, the subject of costs versus benefits has been subjective. The benefits to be gained by any control system are to a large degree intangible. In order for a manager to make a decision about implementing a bar coding system (or any automated data entry system); he

must weigh the measurable costs against the tangible benefits, then use his judgment and experience when applying a factor for the intangible benefits.

The benefits to be gained through bar coding seem only to be limited by their users' imagination and creativity. Bar codes are a tool and their power is not in the muscles of their users, but in their minds. As found throughout the private sector, only the ultimate user will be able to determine the benefits of bar codes. But, I can't help but remember their unanimous words when asked about returning to their previous methods: "No Way!"

Undoubtedly bar coding will be replaced by a better, more efficient and more accurate system as technology advances. However, there is absolutely no reason for us as managers to shun this "here and now" technology and wait for something better. If it fits, after an objective <u>and</u> subjective analysis then implement it.

APPENDIX A

GLOSSARY

The glossary contained in this appendix was drawn primarily from Handbook of Bar Coding Systems by Harry E. Burke. It provides definitions for many of the terms and acronyms used in this thesis. Additionally, selected terms relating specifically to bar coding and other methods of automatic data entry have been included for future reference.

AIAG. An acronym for Automotive Industry Action Group.

AIM. An acronym for Automatic Identification Manufacturers, Inc.

Alphanumeric Bar Code. A mixture of bar configurations representing alphabetic and numeric symbols.

ANSI. The code described in American National Standard Code Information Interchange, ANSI X3.4-1968, used for information interchange among data-processing systems, communication systems, and associated equipment. The ASCII set consists of control characters and graphic characters.

Aspect Ratio. The ratio of height to width of a bar code symbol. A code twice as high as wide would have an aspect ratio of 2; a code twice as wide as high would have an aspect ratio of 0.5.

Assigned Bit. Either a bar or a space which is assigned zero or one significance because of its particular width.

Automatic Action. Mechanical action having a self-acting or self-regulating mechanism.

Automatic Read. The reading of a bar code message by some automated means, either beam-scanning or linear array.

Automation. The technique of making an apparatus, a process or a system operate automatically.

Bad Read. Data output condition where the scanned data does not agree with the printed message.

Bar. One single horizontal or vertical line.

BARCAPS. An acronym for Bar Code Accountable Property System.

Bar Code. Ciphers constructed from a series of dark and light bars organized, according to specific rules, into various patterns which represent letters, numerals, and other human-readable symbols. Coding variables include the number of dark bars, the relative positions of dark bars within a code structure, the variable widths of the dark bars, the variable widths of the light bars, and their relative positions.

Bar Code Density. The number of characters that a code can represent, per linear inch.

Bar Code Symbol. The entire symbol, made up of several bar code ciphers, which stands for a complete product number, etc.

Bar Coding. A means for the deferred transfer of information from one computer to another via a printed image without detailed processing or transcribing by a human operator.

Bar Length. Measurement of the long dimension of a bar.

Bar Ratio. A particular bar code's relationship of the stroke width of the narrow bars (white or black) to the wide bars.

Bar Width Reduction. Deliberate reduction of the width of bars on film masters or printing plates, to compensate for the gain in bar width that takes place during printing. Correct use of bar width reduction results in printed bar code symbols that are within specifications.

Bearer Bars. A rectangular bar pattern circumscribing a bar coded message horizontally and vertically. A bearer bar is employed to provide support for a printing place, usually when printing on corrugated board.

Bidirectional Code. A bar code that permits reading either from left to right or from right to left.

Binary Code. A code which makes use of two distinct characters, usually 0 and 1. A code using the binary number system (powers of two). In a broad sense, all bar codes are binary, since they use only light and dark areas.

Bit. A one or a zero.

Bit-Stream. A continuous stream of ones and zeros.

Black Bar. Bar printed in readable ink.

Byte. A group of bits which together are assigned character significance.

Character. A single number or letter, or a single bar code character made up of bars and spaces. A human-readable character is a conventional number or letter; a machine-readable character is the equivalent bar code. The machine-readable version is more precisely called a cipher.

Character Set. The family of characters available for enciphering within a coding scheme.

Check Digit (Check Sum). A cipher included within a code's overhead, used for error detection.

Cipher. A member of a family of ciphers, wherein each member constitutes a unique symbol which is substituted, on a one-to-one basis for a letter (or other symbol) of an original text. Bar code ciphers are machine-readable.

Clear Zone. The blank area around the four sides of a bar coded message, provided so that other printing will not interfere with reading the code.

Code. A system of symbols (letters, numbers, words) used to designate a letter, a number, a phrase, or perhaps a whole sentence or other complete thought.

Code Density. The number of ciphers per inch permitted by code specifications.

CODE-39. An alphanumeric code trademarked by Interface Mechanisms. Code adopted by the Department of Defense. Sometimes referred to as Code 3 of 9.

Code Width. The total length of a bar coded message.

Continuous Code. A bar coding scheme wherein each cipher ends in a space. That is, the spaces between ciphers are a part of the code.

Database. An organized collection of stored data controlled by a specific schema and having a level of controlled redundancy.

Data **Independence.** The property of the logical or physical structure of a database (scheme) that allows the structure to be changed without the application program's view of the data having to be changed.

Data Item. The smallest unit of data that has meaning. Synonymous with field.

Data Set. A named collection of logically related data items having one of several prescribed arrangements--direct, random, or serial.

Depth of Field. Maximum spacing of a wand tip above the printed surface, or the dimension between a minimum distance and a maximum distance over which a read head can detect a message printed on a coded surface.

Discrete Code. A bar code where each cipher begins and ends with a bar. That is, the spaces between ciphers are not a part of the code and so can vary freely.

DLA. An acronym for Defense Logistics Agency.

DOD. An acronym for Department of Defense.

DSSG. An acronym for Distribution Symbology Study Group.

Dual Orientation. Identical bar coded messages printed with normal and stacked orientation, so that one can be read regardless of how the label is turned in relation to a read head.

EAN. An acronym for European Article Number. A bar code system corresponding to the UPC system in the United States. Many scanners can be set up to read both EAN and UPC bar codes.

EPOS. An acronym for Electronic Point of Sale. It is a current project in the FMSO LOGMARS Project Office.

Element. The minimum width of bar, and the minimum width of space, which can be printed and detected by a bar code system. The same as "X."

Elemental Bit. The assignment meaning of "one" to an elemental dark bar, and of "zero" to an elemental light bar.

Error Rate. The total number of errors per number of readings attempted (or per number of readings accomplished).

Field. The smallest unit of named data. (Data item, data element, elementary item.)

First Read Rate. The number of correct reads divided by the number of attempted reads.

FMSO. An acronym for Naval Fleet Material Support Office.

FRLBPH. An acronym for Florida Regional Library for the Blind and Physically Handicapped.

Guard Bars. The tall bars used at the sides and center of UPC and EAN bar code symbols. They provide reference points for scanning.

Hand Scanning. Use of a hand-held wand or scanner. Portable scanners are important for inventorying, reading shelf labels, etc.

HIBCC. An acronym for Health Industry Bar Code Council.

Hit. The achievement of an acceptable read in nine or fewer scans of a coded message sample.

Identification. Establishing the identity (so as to maximize security) of human participants by some physical attribute--fingerprint, voice print, palm print, or the like. Otherwise, something known like a password or cipher, and/or something carried like a key or card, must suffice.

Intercipher Gap. The space between the last bar of one cipher and first bar of an adjacent cipher of a discrete bar coded message.

Interleaved Bar Code. A combination in which both black and white bars are significant, but where the black bars relate to one cipher and the white bars to some other cipher.

Interleaved 2 of 5. A compact number-only bar code with two wide components out of five, per character.

IRDF. An acronym of Issue Receipt Data Form, a bar coded replacement for DD 1348-1.

Item Code. In the UPC system, the five-digit number that each manufacturer assigns to each of his products.

Jefferson Chart. A system invented by Thomas Jefferson wherein a number of strips with the ten numerals (or even the complete alphabet) are printed in column along one end of each strip, and their bar code cipher equivalents are printed in column along the other end of that same strip. These strips are then laid side by side and each is moved vertically to the others, until the desired multidigit number appears in line across all the strips. The equivalent bar coded messages will then appear in line, at a particular position across the same strips.

JSG. An acronym for Joint Steering Group. It was established by the OASD in July 1976 for LOGMARS study.

Key. One or more data terms used to identify or locate a record.

Key Punch. A process whereby a card punch receives its instructions from a manually activated keyboard.

Ladder Code. A bar code printed vertically, with individual bars looking like rungs of a ladder.

Laser Scanner. A bar code reading device that uses low-energy laser as the light source.

LCG. An acronym for LOGMARS Coordinating Group. It replaced the Joint Steering Group in February 1982.

LED. An acronym for Light Emitting Diode. A semiconduction device which emits electromagnetic radiation over a very restricted band of light as a result of electrical stimulation.

Light Pen. A hand-held scanning wand.

LOGMARS. An acronym for Logistics Applications of Automated Marking and Reading Symbols.

Magnetic Stripe. Strips of magnetic tape added along one edge of a document--an ID card, credit card, etc.

Message. A finite string of ciphers which carry a complete unit of information.

Message Length. The number of ciphers contained in a single coded message.

MICR. An acronym for Magnetic Ink Character Recognition. A technology for encoding numbers on checks with magnetic ink.

Misread. A bad read or substitution error.

NDC. An acronym for National Drug Code. The related Items Code: ten digit code numbers administered by the U.S. Food and Drug Administration, expressed in the UPC bar code symbol. These numbers use the number system character 3 as the first digit, rather than the 0 used by regular supermarket items.

Nominal Size. The standard size for a bar code symbol. Most code can be used over a range of magnifications (0.80 to 1.20 of nominal.)

Nonread. Absence of data output after an operator has scanned a machine-readable label.

Normal Bar Code. A bar code printed in an orientation giving the visual effect of a picket fence.

NPS. An acronym for Naval Postgraduate School, Monterey, California.

Number System Character. The first (left-hand) digit in a UPC number; it identifies different number systems. Regular items carry a 0; drug (NDC/HRI) items carry a 3; random weight items have a 2.

Numeric Bar Code. A code consisting only of ciphers representing numeric data, possibly with a few additional symbols.

Nybble. A meaningful group of bits smaller than a byte.

OASD. An acronym for the Office of the Assistant Secretary of Defense.

OCR. An acronym for Optical Character Recognition. The process whereby human-readable characters are read by instrumented means.

OCR-A. A font designed for maximum machine readability.

OCR-B. A specific style of letters and numbers used for the human-readable characters specific for use with the UPC, EAN, and UCS/TCS bar code symbols.

OCR Ink. Carbon ink (or ink which can be read by infrared scan).

Omnidirectional. Able to read a bar code symbol from any angle. Supermarket checkout laser scanners are omnidirectional; as long as the bar code passes over the scanner window, it can be read, regardless of how it is turned.

Overhead. The fixed amount of a bar code message consumed in the START/STOP, message checking, and (in some codes) character-set designator ciphers.

PBCR. An acronym for Portable Bar Code Reader.

Packing Density. A measure of the amount of information which can be placed in a unit area or (in the case of bar codes) along a unit line.

Page Reader. An instrument which can read pages of information printed in an OCR font. These cannot be used to read labels on any other item.

Parity. System for encoding ciphers as "odd" or "even" bar code patterns. Not related to whether the original number is odd or even. Used to provide a self-checking feature in bar codes.

Parity Bar (Parity Bit, Parity Module). In various bar code systems, a specific arrangement to provide self-checking.

Percent Successful Reading Rate. Scan rate minus error rate, divided by scan rate, times one hundred.

POS. An acronym for Point-of-Sale. Shorthand for data-entry systems such as supermarket laser scanner checkouts.

PSE. An acronym for Personal Support Equipment. The furnishings in Navy Bachelor Quarters are classified as PSE.

Quiet Zone. The area immediately preceding the START cipher and following the STOP Cipher, which contains no marking.

Qwerty Keyboard. The commonly used, familiar typewriter keyboard.

Read Acceptance Probability. The number of hits divided by the number of samples scanned.

Read Area. Area covered by a scanner. Especially important in material-handling applications, as when scanners read cartons on a conveyor belt. Bar codes must reliably pass through the read area.

Read Integrity. The number of correct reads divided by the probability of hits.

Read Reliability. The combination of a high first read rate and a low substitution error rate.

Record. A group of related data items treated as a unit.

Reflectance. Amount of light reflected back from a surface. Reflectance is measured under specified conditions in which a surface coated with barium sulfate is considered to be a perfect diffuse reflector of light. (Diffuse reflection scatters light in all directions.) Various instruments are available to measure reflectance directly.

Resolution. The dimension of the smallest code element than can be printed by a bar code printer or identified by a bar code reader; or the larger of these two, when discussing a bar code system in general.

SAG. An acronym for Senior Advisory Group. It was established by the OASD in July 1976 for the LOGMARS project.

Scan. Movement of a scanner light beam over a bar code (or of the bar code past the light beam).

Scan Area. The area covered by a scanner. (Same as read area.)

Scanner. Device that converts bar code symbols to electrical signals for data input and storage. Used interchangeably with "reader"; and, a device used to read and identify a pattern of coded information.

Scanning Range. Maximum distance at which a scanner can read bar codes. Equal to optical throw plus depth of field.

Scanning Wand. A hand-held scanning device connected to a data-input or storage device.

Scan Rate. Total number of scans per unit of time.

Schema. The structure of a database.

Scob. A pattern defect.

SER. An acronym for Substitution Error Rate.

Slot Reader. An instrument which reads a machine-readable header from a document when that document is drawn through a slot.

Space. The lighter element of a bar code.

Spectral Response. Sensitivity of a scanner or other device to different colors of light. Lasers used in laser scanners generally operate in the red part of the spectrum, which affects the colors that can be used for printing scannable bar codes.

Spectral Reflection. Mirror-like reflection that occurs at a specified angle. Shiny surfaces producing specular reflections may cause problems for bar code scanners.

Stacked Bar Code. A bar code printed in an orientation giving the visual effect of a ladder.

Start Cipher/Stop Cipher. A bar code representing "beginning of code" or "end of code." It also indicates to the scanner whether the code is being read backward and should be reversed.

STATLOC. An acronym for Statistical Location Survey. It is a current project in the FMSO LOGMARS Project Office.

Straight Bar Code. One in which the white spaces between black bars are not a part of the code.

Stroke. Thickness of a bar.

Substitution Error Rate. A quantification of the condition which exists when an attempt to read a cipher results in a wrong conclusion--a wrong reading. The rate at which a substitution error occurs is an important system criterion, as it measures the quality of information held in a data base. May also be applied to manually entered data. Is usually expressed as the number of errors in a given number of entries or as a percentage of the number of entries.

Symbol. Combination of all necessary bar code ciphers to form a complete data message; data, START/STOP, and check digits.

Symbol Density. Amount of data contained per inch in a bar code symbol. Limited by the width of the narrowest bar or space.

Transport Case Symbol. European equivalent to the UCS (Uniform Container Symbol) for shipping containers.

UCS. An acronym for Uniform Container Symbol. Bar code message designed for printing on corrugated shipping containers; result of Distribution Symbology Study Group.

UPC. An acronym for Universal Product Code. A ten-digit code number that identifies a wide range of products and their manufacturers; printed as the UPC symbol (bar code) on packages.

UPCC. An acronym for Uniform Product Code Council. Organization responsible for overseeing and administering the Universal Product Code.

USD. An acronym for Uniform Symbol Description. Specifications set up by AIM (Automatic Identification Manufacturers) for bar code standards.

USD-1. Interleaved 2/5.

USD-2. Subset CODE-39. The strongest possible alphanumeric code.

USD-3. CODE-39 (Trademark of Interface Mechanisms, Inc.). It includes four out-of-pattern ciphers.

USD-4. CODABAR.

Version A, Version E. Version A is the standard UPC bar code symbol. Version E is a special shortened version, requiring less space, formed by use of zero suppression.

Void. White or light area in a bar caused by printing error. It can cause a bar to scan as a space.

VSDA. An acronym for Video Software Dealers Association.

Wand. A penlike hand-held device used to read bar codes by passing its tip over the printed marks and transmitting optically obtained message data for electronic decode. It is sometimes called a light-pen, but this term is easily confused with the light-pens used as curser controls for CRT terminals.

Wand Reader. A hand-held device operated by movement over the area to be read.

Word. A complete "thought" as indicated by a combination of characters or their equivalent bar code ciphers.

"X". The minimum width of bar, or space, which can be printed with integrity when using a given printing process.

APPENDIX B

AUTOMATIC DATA ENTRY AND IDENTIFICATION METHODS

This appendix presents a brief description of selected automatic data entry and identification methods. It was extracted primarily from "The World of Automatic Identification," an article by Russ Adams which was published in Bar Code News, Volume 6, Number 3, pages 6-18, May 1986. A tabular comparison of the readers and information carriers for the various methods discussed is presented in Table B.1 at the end of this appendix. Additionally, a graphic comparison of the substitution error rates for keyboard, OCR, and bar code data entry methods is presented in Figure B.1 which follows Table B.1 at the end of this appendix.

This appendix is organized into eight sections that present a brief overview of manual data entry and seven automatic data entry and/or identification methods. The advantages and disadvantages presented for a specific method are based on facts, but should not be considered as absolute or all inclusive. Since the comparison of two methods is based both on factual and subjective analysis, no attempt has been made to conclusively identify one automatic method as the "best" for all situations. In fact, there is not "one" method that fits every situation. Additionally, industry experts are not in complete agreement on the attributes or shortcomings of every system.

1. MANUAL DATA ENTRY

There is a limit to the power, speed, and accuracy of every computer. That limit is the result of a single device that was designed more than one hundred years ago. It has remained virtually unchanged during all that time. The horse-and-buggy device that keeps computers operating at a trot is the standard data entry keyboard.

Typing on keyboards has been the traditional way to enter data into computers. Typing requires trained people. And trained people cost money.

The expense of data entry has always been an embarrassment when examining the cost effectiveness of a computer system. The fact is that computers are not cost effective without lots of data to digest. But the cost of entering

and updating all that data by keyboard often is more expensive than the hardware and software combined. And it's an on-going expense.

Keyboard entry has also been included in the comparison of automatic data entry and identification methods in Table B.1 at the end of this appendix.

2. BAR CODE

Because bar coding and its applications were the subject of this thesis, any additional description would be redundant. Therefore, the following lists of advantages and disadvantages are merely a review and complementary to this appendix.

a. Advantages

-- Inexpensive.

-- Full character set.

-- Material imprintable.

-- Easy to print and copy.

-- Word processing compatible.

-- Non-critical wanding.

-- Beam scannable.

-- Low error rate.

b. Disadvantages

-- Low information density.

-- Large number of incompatible codes.

3. MAGNETIC STRIPE

Just as bar coding gained its familiarity through the "stripes" on products in the supermarkets, magnetic strips have become familiar through their use on credit cards and automatic teller machine (ATM) cards. In fact, the basic technology behind bar codes and magnetic stripes is really not that different. While bar coding relies upon encoding information in black and white stripes, magnetic stripe recording encodes its information in plus and minus pickets. And, in both situations the information is recovered by scanning the entire code with a read head.

However, some obvious differences exist. Magnetic material is more homogeneous than most printing materials; which means that magnetic stripes can carry far more information in a given space than bar codes. In addition to the information density potential for magnetic stripes, their read/write capability is clearly advantageous where the information is subject to change or updating. In fact, magnetic stripes may be the only practical method for this application.

But these attributes have limited applications and are susceptible to undetectable damage. This damage may occur due to an inadvertent exposure to a magnetic field resulting in the erasure of all data contained on the stripe, or it may be due to an intentional alteration of the data. The

latter obviously poses a bigger problem because of the potential security breech and fraudulent use implications.

Consequently, the situation for magnetic stripes is a bit ironic. They have been widely accepted for use by financial institutions and corporate security organizations.

On a more positive note, magnetic stripes perform many functions very well. In fact, magnetic slot readers are among the toughest, most indestructible, and longest lasting maintenance-free equipment available. The following lists include some of their most prominent advantages and disadvantages.

a. Advantages

-- Read/Write capability.

-- High information density.

-- Full character set.

-- Non-critical wanding.

-- Low error rate.

b. Disadvantages

-- Not human readable.

-- Modifiable.

-- Word processing incompatible.

-- Difficult to print and copy.

-- Only contact scannable.

-- Restricted format.

-- Moderately expensive information carrier.

-- Cannot be read through a plastic cover.

4. OPTICAL CHARACTER RECOGNITION

Although the cost of processing and storing data has declined during the last two decades, companies now pay more than twice what they did 20 years ago to have operators enter data manually. According to the Institute for Computer Sciences and Technology at the U.S. Department of Commerce, data entry can often represent as much as 30 to 50 percent of an organization's data processing budget.

Current demand for fast, reliable data entry methods has supported development of a variety of methods. One of these methods, optical character recognition (OCR) recognizes human readable characters alone. An optical sensing device is passed over the alphanumeric characters and converts them into electronic signals. These signals go through a series of recognition and validation programs that transform them into precise data.

Generally, OCR can present information at a higher density than bar code. Because it is human readable, it can be used in manual data entry systems. But OCR is more prone to error and the reading equipment is more expensive than bar code.

There are two types of OCR systems. One uses a handheld OCR scanner to scan a short line of text printed in a special OCR font. This OCR system is quite similar in purpose to bar code. Handheld OCR systems have been used by non-grocery retailers in a variety of point-of-sale (POS)

systems. Many large retailers have tried handheld OCR systems, but have opted recently to convert to bar code. The principle reason has been the poor first-read rate as compared to bar code. Also, they are generally limited to two type fonts specially designed for OCR systems, OCR-A and OCR-B.

The second type of OCR system is the OCR page reader. An OCR page reader is most useful for data capture of existing hard copy. Most page readers can read several different fonts commonly used in document printing, and some can "learn" other fonts as documents are scanned. Other page readers can often read many standard typewriter fonts, and the use of such equipment ca greatly reduce the cost of manually keying information into a computer system. Archiving data with OCR has also proved useful for systems requiring paper copies. For example, a printer using an OCR font daisy wheel can be used to type the documents.

State-of-the-art page readers can read text at the rate of up to 300 pages or more an hour. That's 25 to 50 times faster than the average typist. Word processing systems using OCR are used as input devices for author manuscripts and electronic mail systems. Additionally, they are being used by the Internal Revenue Service to expedite the input of paper 1099 tax forms.

Special OCR systems can also read hand-printed letters and numbers. Such a system is being used by the Internal

Revenue Service to automatically read the 1040EZ tax form. In a system which requires data capture from hand-written forms, this specialized form of OCR has an advantage over bar code.

The following lists of advantages and disadvantages apply to OCR technology as a whole, without regard to a specific application and specialized equipment.

a. Advantages

-- Human readable.

-- Easy to print and copy.

-- Word processing compatible.

-- High information density.

b. Disadvantages

-- Expensive read equipment.

-- Orientation critical.

-- Restricted wanding speed.

-- Restricted character set.

-- Not beam scannable.

-- High error rate.

5. RF IDENTIFICATION

Automatic identification of items is currently dominated by bar code and OCR technologies. However, both of these technologies suffer from two basic limitations: relatively short read range and poor readability under harsh environmental conditions. A relatively unique, new technology, Radio Frequency (RF) Identification, is rapidly becoming the

system of choice in applications where harsh environments make optical based identification systems impractical.

The most commonly used automatic identification system incorporates bar coded labels read by scanners. Although bar codes can be read at a distance with a laser scanner, they are subject to environmental constraints. They will not read successfully if painted over, covered by dirt, burned, or damaged by chemicals. Other automatic identification technologies such as optical character recognition and magnetic strip cannot be read at a distance and are less resistant to harsh environments than bar codes.

Radio Frequency Identification should not be confused with radio frequency based bar code systems or the non-unique electronic article surveillance tags many department stores attach to merchandise to reduce theft. Radio frequency based bar code systems use a radio transceiver to provide a wireless link to a standard bar code reader, while the department store tags are really nothing more than a form of metal detector.

On the other hand, RF Identification systems produce a radio signal that is unique to the item that has been tagged. These systems are based on two technologies. One type of RF Identification system is based on the use of a small CMOS radio transponder. A radio receiver and a transmitter chip are encased in a tag. The receiver and transmitter circuitry can be powered by a five-year lithium

battery or by some of the energy received from the polling reader. A reader transmits a radio signal which is received by the tag's radio receiver. The received signal triggers the tag's transmitter to transmit a unique coded message which is received by the reader's receiver. The information is decoded and passed to a host computer, and the tag has been identified. The CMOS based system has an operating range of up to 1000 feet.

The second type of RF Identification is based on a concept analogous to printed bar code or OCR symbols. This second system utilizes a phenomenon of nature called surface acoustic waves or SAW for short. The SAW based system uses a low-power microwave transmitter that transmits a beam of microwaves onto the SAW tag. The tag uniquely modifies the microwave signal and the reflected microwave beam carries the unique modification. The SAW based system can operate up to six feet from the reader.

The radio frequency transponder is a technology that has not received widespread use because of its cost. But the system makes sense for special types of applications. Identification Devices, Inc., of Westminster, Colorado, demonstrated a system that used an electronic transponder to automatically identify individual dairy cows as they entered a feed station. The transponder was designed as a collar tag and contained a silicon chip coded with a unique serial

number. The code was broadcast when the chip was activated by a low-power radio signal.

Another RF system from Cotag, a company based in Great Britain, uses a five-year battery built into the transponder system. The Cotag transponder is being used by the British Coal Board as a safety device for coal miners. The transponder is formed as a part of the miner lamp worn by the miner. A detector is mounted near the mouth of all coal crushers. If a miner falls onto the coal crusher conveyor, the transponder signals the miner's presence in time to shut down the system.

The advantages of transponder systems are their resistance to hostile environments and their long projected maintenance-free life span. Passive systems are estimated to have a life span as long as 25 years by some reports. Use of such a system for containerized shipment tracking seems ideal. However as previously stated, their primary disadvantage is the high cost of the information carrier (tag).

6. VOICE RECOGNITION

Voice recognition devices are those products which facilitate the interaction between man and machine by the use of voice input. Long included in science fiction literature, these products allow humans to communicate by voice to machines. According to an International Resources Development, Inc. study, the U.S. data entry equipment

market will double during the next decade, with the fastest growth predicted in the voice entry, OCR, and specialized terminal segments.

One of the first commercial speech-recognition devices was an NEC speech-recognition computer, marketed in 1979. Costing $250,000, it allowed a vocabulary of 100 words, but required many training passes to input each word. The computer was never accurate enough in voice recognition to achieve commercial success.

The next breakthrough in voice recognition came in the early 1980's when a small group of companies introduced a number of single application voice recognition products. Capable of smaller vocabularies, with better speech recognition accuracy, these products were designed for factory automation installations and cost between $18,000 and $30,000.

One of the more successful and visible applications of voice recognition during the early 1980's was a system designed for airlines to assist baggage handlers in the movement of baggage to and from planes. Another successful application was designed by quality assurance purposes on assembly lines of General Motors. Although these represented the first commercially successful voice recognition systems, they were designed specifically with one application in mind, and did not gain widespread use.

Various studies predict that the market for voice recognition will grow from $50 million in 1985 to nearly $2.2 billion in 1992. These predictions assume that voice recognition devices will become available for general office automation purposes. Products have been recently introduced which are designed for general office automation applications. They interact with many popular software programs, have a large vocabulary, are easy to install and use, and are relatively inexpensive (as compared to earlier systems).

Voice recognition systems have the advantage of being very adaptive because they use a person for the data collection. The person interprets what is seen and expresses it verbally.

However, that advantage is a source of some significant problems. The system is dependent on the person's ability to verbalize correctly. The systems have their problems too. Most systems are only 99 percent accurate in recognizing words when they are used in quiet environments. Most systems are speaker dependent. That means that the system must be trained for each word that is to be recognized by each user of the system. When there is a shift change, for example, the vocabulary to operate with the new worker must be reloaded into the system.

Voice data entry makes the most sense in applications where people must interpret events, where both hands must be

free all the time, where the environment is quiet, and where a limited number of worker changes occur.

7. SMART CARDS

Another automatic identification technology that appears destined for widespread use is the smart card. A smart card is the size of a credit card. It stores information on its surface and in its interior. The surface information can be stored in printed graphics, bar code, embossing, and magnetic stripe. The interior information is generally stored in a semiconductor microcircuit inside the plastic card.

The smart card was developed in the mid-1970's in France. In the following years, a number of companies based in France worked to develop both the smart card and the associated hardware devices for using the card. Smart card technology was first publicly demonstrated by Honeywell in 1982 at the National Computer Conference held in Houston, Texas. The exhibit showed how the Honeywell Bull CPS smart card could be used for bill payments and for storing medical records.

The U.S. Department of Defense is testing the use of the Honeywell smart card as a secure identification for military personnel requiring access to restricted locations. The U.S. Department of Agriculture is also planning to begin a trial smart card food stamp system in an effort to solve the fraud problem.

In addition to debit card applications, health care applications of smart cards appear to be on the increase. Amrix Corporation of Houston, Texas, is selling a version of the Honeywell smart card to hospitals. The card is helping to bill patients quickly and accurately and the cards will also accept patient medical data.

Smart cards are fast and virtually error-free. Despite the fact that the reading equipment is relatively inexpensive, the smart cards themselves are very costly.

8. VISION SYSTEMS

The term "vision system" encompasses a wide range of devices, from systems that let robots correctly position a bolt into an assembly to devices that read text at a distance. Vision systems that can read text at a distance are within the realm of Automatic Identification. It is the ability to read text at a distance which distinguishes vision systems from OCR devices. Text must be in close proximity to an OCR reading head to be captured.

Vision systems generally use video cameras to capture the data. The camera produces a raster image of the information and the raster image is stored in a computer. Programs in the computer analyze the stored image and recognize the printed information. Vision systems are most useful for checking text information printed on objects on a moving conveyor belt. One application of the technology is checking the printed expiration date and lot number on

pharmaceuticals. A system installed at Armour Pharmaceutical in Kankakee, Illinois, by Parish Automation, automatically verifies that the correct date and lot code is printed on each bottle of drugs as it moves down the production line. The system claims a false read rate of 2 in 10,000; however, sufficient data are not available to establish a credible substitution error rate.

Vision systems are to OCR automatic data entry and identification as laser scanners are to bar code. Perhaps their biggest drawback, as is commonly experienced in most new technologies, is the extremely high cost of reading equipment.

COMPARISON OF DATA ENTRY METHODS

	Reader				Information Carrier			
	Price	Distance	Speed*	Substitution Error Rate	Price	Hostile Environment Resistance	Re-Codable	Requires Operator
Keyboard	$100-500	Contact	6 seconds	1 in 300	Low	Low	Yes	Yes
Bar Code: Contact Reader	$100-2000	Contact to 5 mm	1-2 seconds	1 in 3 million	Low	Low to Moderate	No	Yes
Bar Code: Non-Contact Reader	$1000-7500	Contact to 3 meters	.1 second	1 in 3 million	Low	Low to Moderate	No	Handheld: Yes Fixed: No
OCR: Handheld/Slot	$500-2000	Contact to 5 mm	4 seconds	1 in 10,000	Low	Low	No	Depends on Reader
OCR: Page Reader	$500-10,000	Contact	4-6 seconds	1 in 10,000	Low	Low	No	No
RF: Passive (SAW)	$1000-$2000	Under 2 meters	Less than .1 second	Virtually None	High	High	No	No
RF: Active (CMOS)	$700-$2500	Under 10 meters	Less than .1 second	Virtually None	High	High	Yes	No
Magnetic Stripe	$100-500	Contact	1-2 seconds	N/A	Moderate	Low	Yes	Depends on Reader
Machine Vision	$20,000 to $50,000	Under 3 meters	Less than .5 seconds	N/A	Low	Low	No	No
Voice Recognition	$1000 to $30,000	Under .5 meters	8 seconds	N/A	Low	Low	Yes	Yes
Smart Card	$500 to $2000	Contact	Less than .1 second	Virtually None	High	High	Yes	No

* To read a 12 character field
N/A Not available

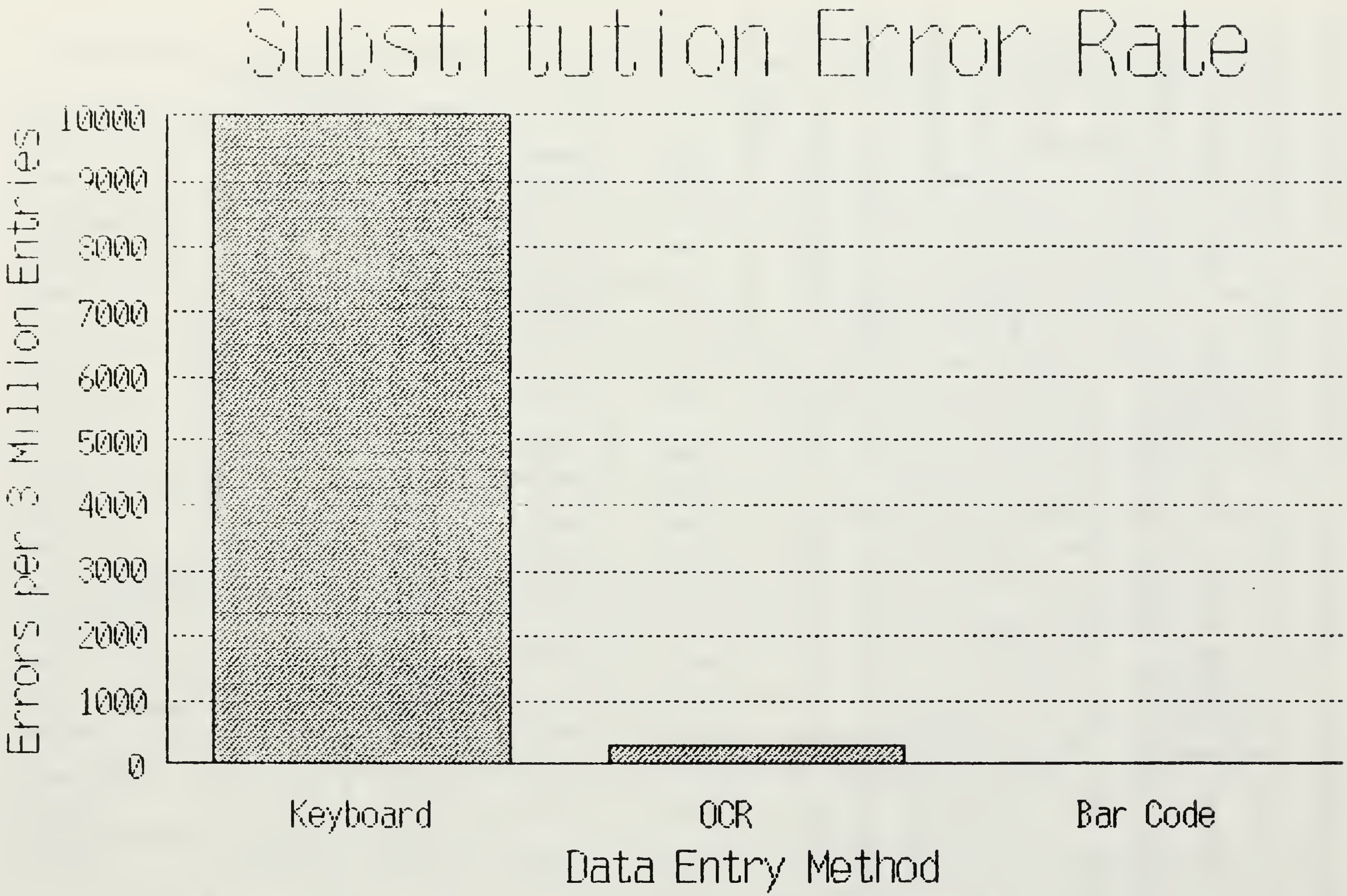


Figure B.1 Comparison of Substitution Error Rates for Keyboard, OCR, and Bar Code Data Entry Methods

APPENDIX C

WOODLAND AND SILVER PATENT FIGURES

This appendix consists of the figures filed by Norman J. Woodland and Bernard Silver with their patent application. The figures are excerpts from "The Fathers Of Bar Code" by Russ Adams. The article was published in Bar Code News, Vol. 6, No. 2, pp. 18-22, March/April 1986.

Figure C.1 contains the following Woodland and Silver figures:

- Figures 1-9. Examples of a three binary digit straight line bar code pattern invented by Woodland and Silver.
- Figure 10. A bull's eye bar code symbol designed to be scanned in any direction.

Figure C.2 contains the following Woodland and Silver figures:

- Figure 11. A scanning system designed to be used for supermarket checkout.
- Figures 12 and 13. Details of the scanning element.

Figure C.3 contains the following Woodland and Silver figures:

- Figure 14. A block diagram of the electronic decoding circuit.
- Figure 15. A detailed schematic showing the thyratron based decoder circuit.
- Figure 16. A graph of the signal produced by the scanner's photo detector when scanning a symbol.

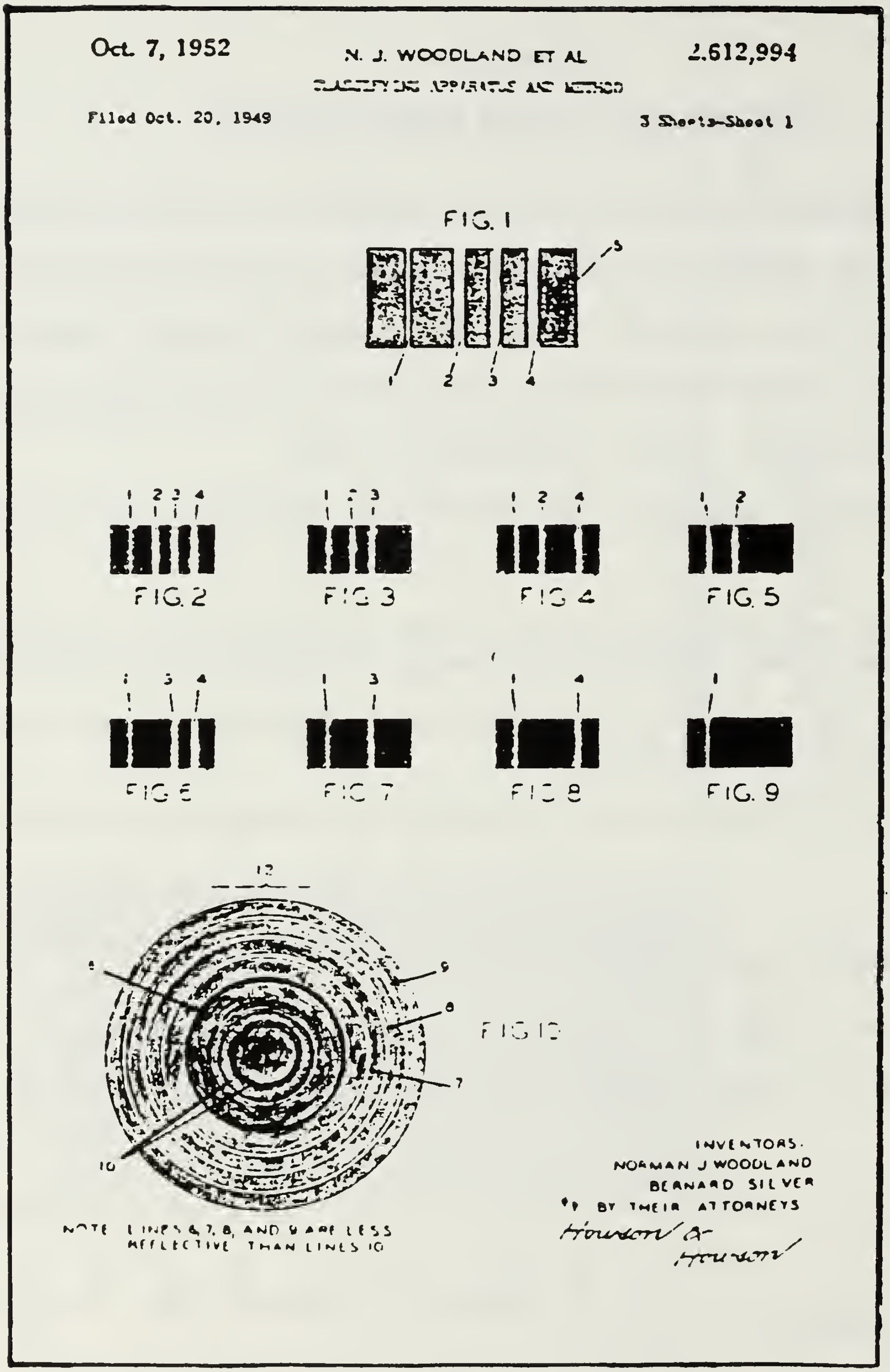


Figure C.1 Woodland & Silver Patent Figures 1-10

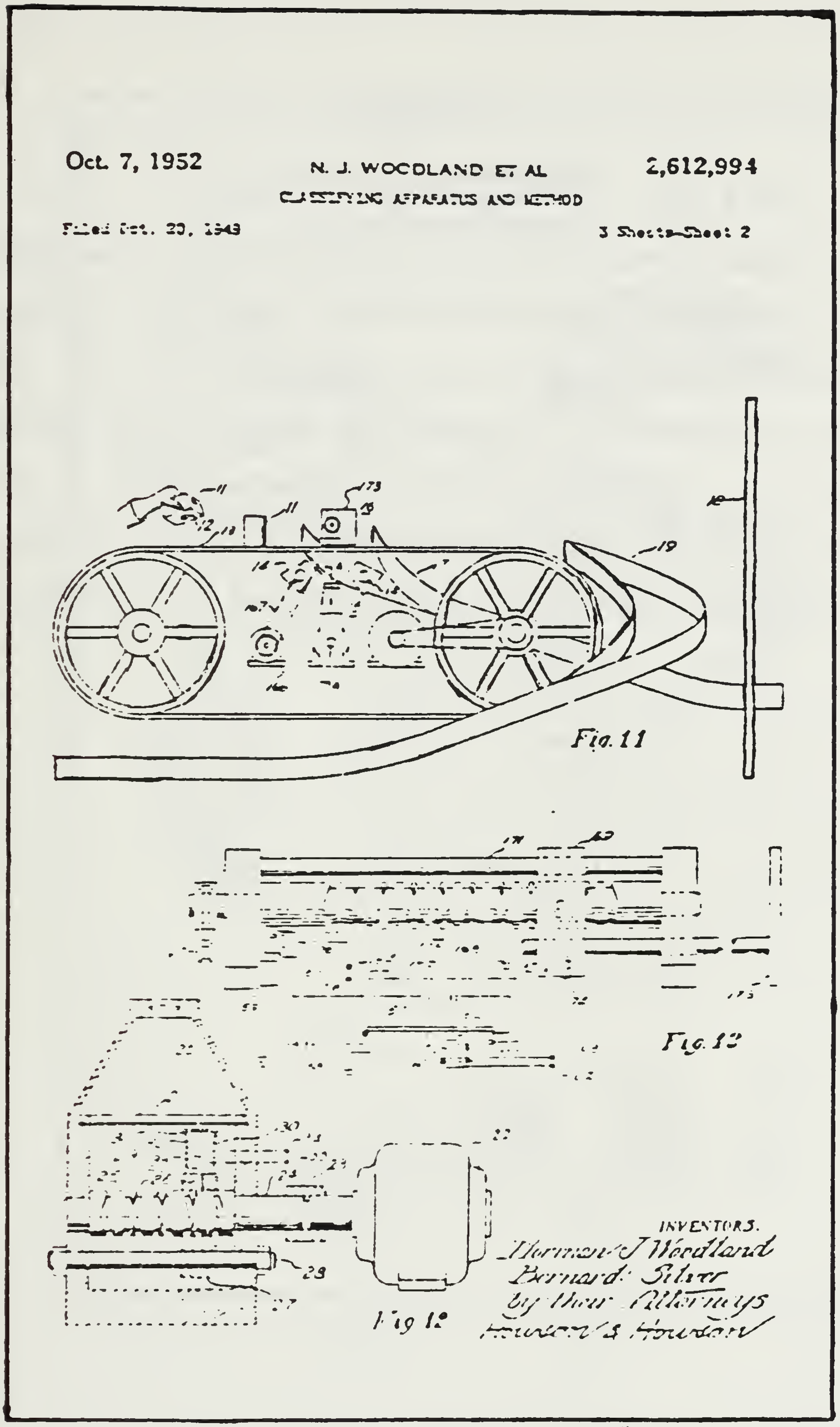


Figure C.2 Woodland & Silver Patent Figures 11-13

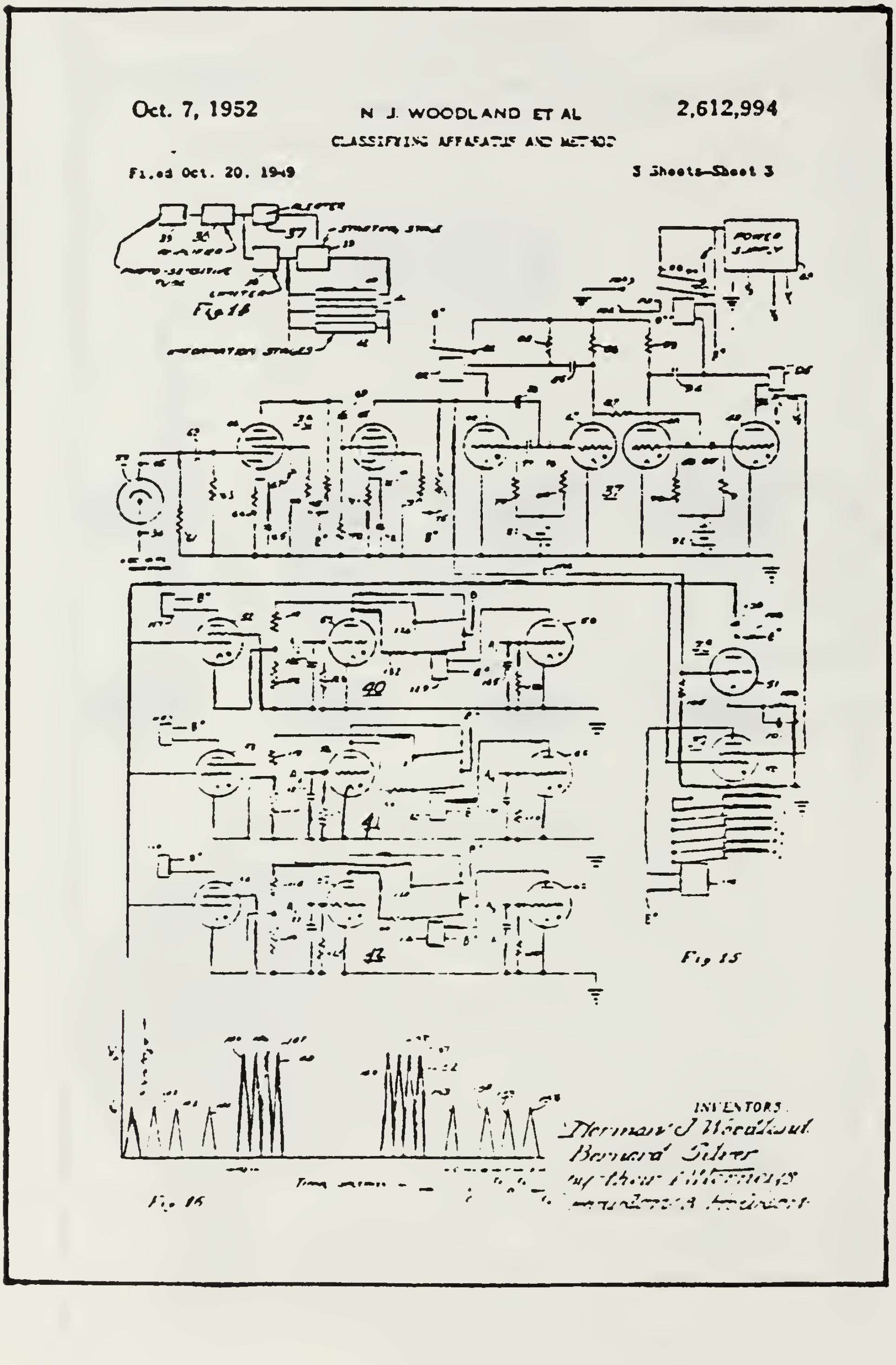


Figure C.3 Woodland & Silver Patent Figures 14-16

APPENDIX D

BAR CODE SYMBOLOGIES

This appendix presents an overview of the six most successful bar code symbologies and a review of eight others. It was extracted from "Bar Code Symbology--Some Observations on Theory and Practice," a paper by David C. Allais. Dr. Allais is the president of Interface Mechanisms, Inc. (INTERMEC) and was the author of CODE 39, the Department of Defense standard bar code symbology.

The term symbology refers to the structural characteristics of bar code symbols. Various modern bar code symbols are used to identify objects, locations, persons, and documents. These symbols are printed in a single color on a contrasting background. Such symbols are also "single channel" in that they are machine read with one optical scan line passing through the symbol.

Bar code symbols carry information in the relative widths of their bars and spaces. Each symbology specifies particular rules for encoding this information. The height of the bars contains no interpretive information.

From the late 1960's through about 1976, engineers in many different companies developed their own symbology. Figure D.1 shows selections from this diversity. As with any technical structure, bar code symbols embody tradeoffs between conflicting desirable properties. These properties include:

a. A large character set, i.e., alphanumeric.

b. Discrete structure with loosely toleranced gaps between characters.

c. Self-checking.

d. Constant character width.

e. Same number of bars for all characters.

f. Structural simplicity (two different widths of elements as opposed to three or more different widths).

g. Amenable to variable speed scanning including acceleration or deceleration within a scan.

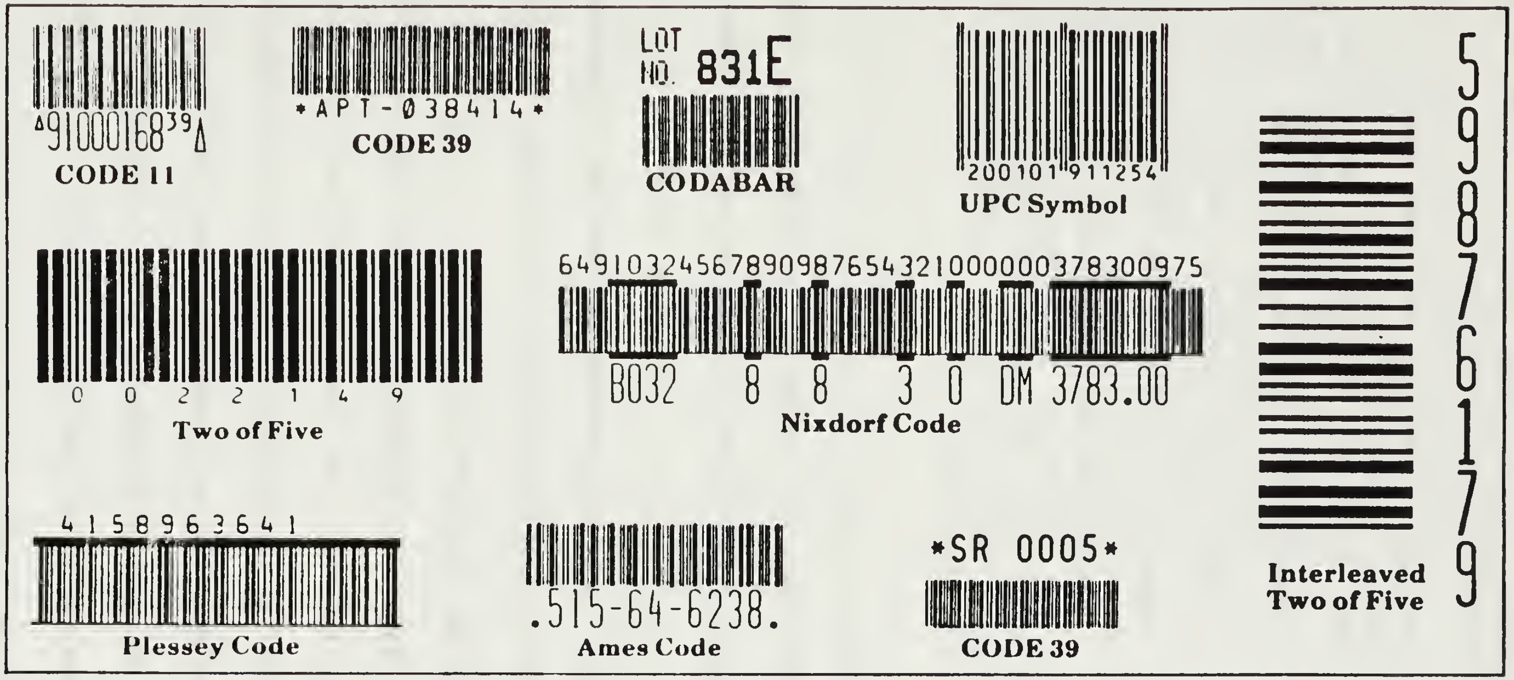


Figure D.1 Sample Bar Code Symbols

h. Generous tolerances for the printed symbol.

i. Generous decoding tolerances left for the scanner in addition to the printing tolerance.

j. High density (symbol occupies minimum printed area).

The first and last properties (large character set and high density) are in conflict with many of the other desirable properties. Those symbologies which have become standards represent reasonable tradeoffs which are appropriate for particular industries and applications. Table D.1, at the end of this appendix, presents a comparison of seven selected bar code symbologies.

1. TWO OF FIVE CODE

Two of Five Code has its origins in the late 1960's. It has been supported by Identicon Corporation and other equipment suppliers.

It has been used for warehouse sortation systems, photofinishing envelope identification, and more recently for sequentially numbered airline tickets.

Two of Five Code is simple and straightforward. All information is contained in the width of bars with the spaces only separating individual bars. Bars may be either wide or narrow, where the wide bar is conventionally three times the width of the narrow bar. Spaces may be any reasonable width but are typically equal to the narrow bars. Narrow bars are identified as a "zero" bit and wide bars as a "one" bit. The code structure is easily remembered by

associating the bar positions from left to right with weighting factors 1, 2, 4, 7, and parity. Exceptions to this "rule" are zero, start, and stop.

Two of Five Code is discrete since the white space between characters is not part of the code and can be loosely toleranced. Discrete codes are easily printed by formed font printing devices such as letterpress numbering heads which can be made very accurate within a single character but are somewhat variable in the space between adjacent characters. Two of Five Code is also self-checking.

When the wide bar to narrow bar ratio is 3:1 and the spaces equal one unit, each data character requires 14 units of width including the gap between characters. If the wide to narrow ratio were reduced to 2:1, each character would still require 12 units. This relatively low density (large number of units per character) is the primary disadvantage of Two of Five Code compared with other numeric symbologies.

The Start and Stop characters have sometimes been shortened to 00 for the Start code and 10 for the Stop code. This arrangement is the same as used for Interleaved 2 of 5 to be described in the next section. Another variation has been to use narrow printed marks separating white spaces of variable width. In this case the encoding is simply reversed so that the spaces carry meaning and the bars act as separators. These variations require specially

programmed readers. An example of a Two of Five symbol was shown in Figure D.1.

2. INTERLEAVED TWO OF FIVE

In October 1972, INTERMEC proposed certain bar code printing equipment to Computer Identics. In this context a problem arose over the low density of Two of Five Code, coupled with a limitation on bar height imposed by the printing equipment. The use of Two of Five Code would have resulted in a long, slender bar code symbol which was deemed unsuitable for laser scanning in a warehouse. The Interleaved 2 of 5 symbology was proposed as a solution.

Interleaved 2 of 5 has been widely accepted as a numeric bar code symbology in warehousing and heavy industrial applications. Its use has been particularly prominent in the automobile industry. Interleaved 2 of 5 has recently been recommended by the Distribution Symbology Study Group as a standard for numeric labeling of corrugated shipping containers. In November 1981, it was adopted by the Uniform Product Code Council as the standard symbology for use on outer shipping containers for the grocery industry.

The encoding technique in Interleaved 2 of 5 is the same as for Two of Five Code except that both bars and spaces are coded. The odd numbered digits are represented in the bars while the even numbered digits are represented in the spaces. The Start character to the left of the symbol consists of the sequence narrow bar, narrow space, narrow

bar, narrow space, while the Stop character to the right of the symbol consists of a wide bar, narrow space, narrow bar.

Current specifications require that the Interleaved 2 of 5 symbol contain an even number of digits. For data comprising an odd number of digits it is recommended that a leading zero be added to the data before encoding. Some earlier usage of the Interleaved 2 of 5 symbology allowed the last character, represented by the last five spaces before the Stop code, to be a Null character. The Null character is now strongly discouraged as it tends to reduce the security of the symbol and it restricts the flexibility of the reader designer in choosing his decoding algorithm.

Interleaved 2 of 5 is self-checking but is continuous rather than discrete. Specifications allow the nominal width of wide elements to range between two times and three times the nominal width of narrow elements unless the narrow elements are less than .02 inch (.5 mm) in which case this ratio must exceed 2.2.

Consider for example a six-digit label with a wide to narrow ratio of 2.5 and a unit size of .02 inch. The Two of Five symbol (excluding quiet zones) occupies 95 units equal to 1.9 inches, compared with the Interleaved 2 of 5 symbol which occupies 56.5 units equal to 1.13 inches. In this example (excluding quiet zones) the Interleaved 2 of 5 symbol is only 60 percent as long as the corresponding Two of Five.

Interleaved 2 of 5 is most commonly used without a check digit and with scanners which anticipate the exact number of digits in each symbol. When a scanner is programmed to read variable length Interleaved 2 of 5 messages, it is possible for a partial scan to be interpreted as a valid shorter message. An example of an Interleaved 2 of 5 symbol was shown in Figure D.1 and a comparison of it to six other symbologies is included in Table D.1.

3. CODE 39

Prior to 1974, the available bar codes were limited to the ten digits plus a few additional characters. But in January 1975, INTERMEC introduced CODE 39, an alphanumeric bar code symbology.

CODE 39 has since enjoyed broad acceptance in manufacturing, hospitals, libraries, universities, and government agencies. In 1980, the U.S. Department of Defense standardized on CODE 39 as the DOD standard symbology. In 1981, the Distribution Symbology Study Group recommended CODE 39 for use in alphanumeric labeling of corrugated shipping containers.

CODE 39 (also known as 3 of 9) is so named because the original concept provided for 39 data characters. The name also derives from its three out of nine structure wherein three of nine elements are wide and the remaining six are narrow. CODE 39 is basically an extension of Two of Five to

represent the letters of the alphabet and selected symbols in addition to the ten digits.

Each character in CODE 39 is represented by a stand alone group of five bars and their four included spaces. Two of the five bars are wide (given ten possibilities) and one of the four spaces is wide, giving four times ten equals forty possible characters. Four additional characters ($, /, +, and %) are structured with all the bars narrow and three spaces wide. The complete character set includes a Start/Stop character (conventionally interpreted with an asterisk) and forty-three data characters consisting of the ten digits, the twenty-six letters of the alphabet, space, and the six symbols -, . $, /, +, and %. For the digits zero through nine, the assignment of wide and narrow bars is the same as in Two of Five Code. CODE 39 is discrete and all forty-four characters are self-checking.

It is often useful to represent in bar code some character or characters which are not in the basic set of forty-three data characters. Such representation is facilitated by the Full ASCII feature of CODE 39. This feature allows all 128 ASCII characters to be represented. The Full ASCII feature operates by using the symbols $, /, +, and % as precedence characters in front of one of the alphabetic characters. For example +B represents a lower case letter b, while $B represents a "control" B (STX).

The strong self-checking property of CODE 39 provides a high level of data security. An analysis shows that resistance to substitution errors varies with print quality. With properly designed scanning equipment and excellent quality symbol printing, one may expect only one substitution error out of 70 million characters scanned. Good printing typical of well-maintained, better quality dot matrix printers corresponds to less than one substitution error in 3,000,000 characters scanned. The U.S. Department of Defense in its LOGMARS testing reported four substitution errors out of 563,243 bar code labels. These labels were separately reported to average 24 characters in length. Thus in this practical test, 3,379,458 bar code characters were scanned for each substitution error. Bar code symbols in the LOGMARS test were printed by various means including printing presses, formed font impact printers, and dot matrix printers.

For those applications which require exceptional data security, an optional check character is suggested in the specification. The vast majority of commercial users find that the strong self-checking properties of CODE 39 are completely adequate without the check character.

In summary, CODE 39 is the most versatile bar code symbology. It is fully alphanumeric and variable length. Because it is discrete and strongly self-checking it can be successfully printed by the broadest variety of equipment

and processes. CODE 39 is the most widely used and widely accepted industrial bar code. Two examples of CODE 39 were shown in Figure D.1 and it is compared with six other bar code symbologies in Table D.1.

A complete specification for CODE 39 including its Full ASCII feature is given in Appendix E.

4. CODABAR

Codabar was developed by Monarch Marking Systems Division of Pitney Bowes for use in retail price labeling systems. The earliest formal documents describing Codabar are Data Sheets, 1972, and a patent application by Bruce Dobras dated March 29, 1972 (resulting in U.S. Patent 3784792 reissued as RE. 28198). A variation of Codabar was among the original proposals for a grocery universal product symbol. After the National Retail Merchants Association standardized on OCR-A for department store price labeling, the promotion of Codabar was redirected toward diversified non-retail applications.

Codabar has been most widely accepted in libraries and medical applications. It has also been extensively used for photo finishing envelopes and preprinted airbills. To a lesser extent, it has been used for industrial bar coding. In 1977, Codabar was adopted as a standard for blood bags by the American Blood Commission.

Codabar is a discrete, self-checking code. Each character is represented by a stand alone group of four bars with

their three included spaces. The 12 principal characters (10 digits, minus sign, and dollar sign) have one wide bar and one wide space. Four additional characters (:, /, ., and +) have three wide bars and no wide spaces. Four different stop/start characters are defined and designated a, b, c, and d. These start/stop characters are constructed using one wide bar and two wide spaces. A complete Codabar symbol begins with one of the stop/start characters followed by some number of data characters and ending with one of the stop/start characters. Since any of the stop/start characters may be used on either end of the symbol, it is possible to encode four bits of information in the choice of start and stop characters.

Codabar is variable length, discrete, and self-checking, making it a versatile symbology. The character set is however limited to 16 data characters. The standard dimensions for bars and spaces in Codabar were originally chosen to optimize performance of certain early printing and reading equipment. Unfortunately, these bar and space dimensions are not even multiples of units. In fact, 18 different widths of bars and spaces are specified, resulting in a superficially complex structure.

Analysis suggests that the self-checking properties of Codabar are similar to those of CODE 39. Given good print quality, substitution errors should occur no more frequently than one out of several million characters scanned. Codabar

is widely and successfully used without check digits. An example of a Codabar symbol was shown in Figure D.1 and it is compared with six other symbologies in Table D.1.

5. CODE 11

CODE 11 was developed by INTERMEC in early 1977 to satisfy specialized requirements for a very high density discrete numeric bar code. The most extensive application of CODE 11 has been labeling telecommunications components and equipment.

The name CODE 11 is derived from the fact that 11 different data characters can be represented in addition to a stop/start character. The character set includes the 10 digits and the dash symbol.

Each character is represented by a stand alone group of three bars with two included spaces. Although CODE 11 is discrete, it is not self-checking since a single printing defect can transpose one character. Data security is obtained by using one or preferably two check digits.

Analysis suggests that CODE 11 using only one check digit has roughly four times the error probability of CODE 39. When CODE 11 is used with the recommended two check digits it becomes more secure than either CODE 39 or Codabar. An example of CODE 11 was shown in Figure D.1 and it is included in the comparison of seven selected bar code symbologies in Table D.1.

6. UPC AND EAN

The concept of automating supermarket checkout using machine readable printed symbols on individual grocery items has intrigued inventors for over three decades. A patent filed October 20, 1949, by Norman J. Woodland and Bernard Silver describes one such printed symbol. (Appendix C contains a reproduction of the figures filed with this patent.) Some 20 years later, in mid 1970, a grocery industry ad hoc committee was formed under the chairmanship of R. Bert Gookin for the purpose of selecting a standard code and symbol for that industry. This ad hoc committee subsequently established guidelines and a symbol selection subcommittee to select an industry standard symbol. Proposals were solicited from interested manufacturers of computers and point-of-sale equipment. Seven equipment manufacturers responded with proposed symbols.

A massive symbol evaluation was undertaken including laboratory tests by Battelle Memorial Institute, printing tolerance test assisted by the Graphics Arts Technical Foundation, printability tests by participating grocery manufacturers and store tests of complete working systems. This effort concluded with the selection of the UPC symbol as the industry standard on April 3, 1973. The final symbol closely resembles the International Business Machines (IBM) proposal. Structural principles for bar code symbols of

this type were described in an October 1971, IBM position paper and in a U.S. patent dated June 28, 1971.

Subsequent to the adoption of the UPC symbol, several additions and enhancements were incorporated into the standard. In August 1975, a Supplemental Code for use with the UPC symbol on periodical and paperback books was established. Foreign interest in UPC lead to adoption of the EAN (European Article Numbering) Code in December 1976. Comparing EAN (also known as World Product Code and as International Article Number) with UPC, both bar codes share a common symbology and are fully compatible. UPC, in fact, is a subset of the more general EAN Code. In April 1978, Version D of the UPC symbol was specified for potential use in non-food retail and other applications which require more than 12 data digits.

UPC was established for the benefit of the supermarket industry to facilitate automatic scanning of item numbers with associated price look-up at the point of sale. Adoption of UPC includes the recorded music industry, the liquor industry, and many non-food items sold in supermarkets. UPC is spreading to other types of retail establishments including discount department stores and convenience stores.

The structure of the UPC symbol and the reasons for selecting that structure are best appreciated by reviewing some of the explicit and implicit criteria for its selection. A primary criterion was to enable packaging companies

to print the UPC symbol along with text and promotional materials directly on grocery packages and labels with virtually zero cost impact. Grocery packages are printed by a variety of printing press processes including lithography (offset), letterpress, gravure, flexography, metal decorating and silk screening. Some of these processes are inherently more precise and controllable than others. A further objective was to choose a symbol which could be scanned in an omnidirectional fashion at the point of sale. Omnidirectional means that any package orientation is acceptable provided the package goes over the scanner symbol side down. Other objectives included the ability to be wand scanned and the ability to be printed by specialized equipment. Additional guidelines included the capability of 99 percent first read rate with a slot scanner and a substitution error rate at the scanner not to exceed one in 10,000 symbols scanned.

Printing presses are subject to ink spread such that the width of printed lines generally exceeds the corresponding line width on the printing plate. The amount of ink spread depends on press conditions, amount and viscosity of ink, and other factors which are difficult to precisely control. International Business Machines proposed a technique which they call delta distance whereby a bar code symbol is made insensitive to uniform ink spread. This property is embodied in the UPC symbol. However, excessive ink spread

could result in some spaces becoming too small for the scanner to resolve and thus a non-scannable symbol.

A complete Version A UPC symbol was shown in Figure D.1. The longer bars at the center divide the symbol into a left half and a right half. Slot scanners are constructed with orthogonal beams (the simplest form being two beams crossing at a 90 degree angle) such that at least one beam will pass through each half symbol regardless of orientation. The bars in each half symbol are sufficiently taller than half symbol width so that this omnidirectional scanning feature can operate reliably while the symbol moves rapidly over the scanner.

Individual UPC/EAN characters are constructed of two bars and two spaces occupying a total of seven modules (or units). Dark modules are associated with Binary "one" and light modules with Binary "zero," so that the sum of these bits equals the number of dark modules in the character. Odd characters have either three or five dark modules while even characters have either two or four dark modules. Twenty possible lefthand and 20 possible righthand characters can be constructed using these rules. Within UPC/EAN only the 10 digits are represented, but each character contains an additional bit of information depending on whether it contains an odd or even number of dark modules. The UPC Version A symbol is constructed using only lefthand odd characters and righthand even characters. Each half

symbol contains a total of six digits. The last digit in the right half is a check digit computed from the preceding 11 information digits. The UPC symbol embodies two levels of checking, the first being the parity of individual characters within the half symbol and the second being the symbol check digit. Scan direction for UPC/EAN is determined from character parity rather than from the asymmetry of stop/start characters in other symbologies.

A shorter UPC Version E symbol is six digits long using only left type characters but employing both odd and even parities. The basic EAN symbol encodes 12 data digits plus a check digit within the same geometry as a UPC symbol. This is accomplished by allowing both odd and even parity for the lefthand characters and arranging them such that three of the six characters have even parity. The 13th digit representation is thus encrypted in the parity sequence of the left half symbol. In UPC Version D, all four parity types of characters are utilized to create a family of compatible omnidirectional symbols of various lengths up to 29 data characters.

The bars and spaces of UPC characters can be either one module, two modules, three modules, or four modules wide. This relationship is nominally exact for the digits 0, 3, 4, 5, 6, and 9. For the digits 1, 2, 7, and 8, however, the nominal bar and space width dimensions are altered so that they are no longer exact multiples of a module. For the

characters 1 and 2, the bars are printed more narrow by 1/13 module width, and for the characters 7 and 8, the bars are widened by 1/13 module. The reason for this shaving or distortion of nominal bar width is that the edge to similar edge measurements are identical for the characters 1 and 7 and for the characters 2 and 8. In these cases it is appropriate for the scanner to measure bar widths in order to separate 1's from 7's and 2's from 8's. All other decoding in UPC can be done using only edge to similar edge measurements which are inherently immune to ink spread. Altering the dimensions of characters 1, 2, 7, and 8 provides improved margins for the scanner in those cases where it is appropriate to measure bar width.

The structure of UPC/EAN is quite different from the industrial symbologies discussed in preceding sections. Printing tolerances for the industrial symbologies are stated only for bar and space widths. In UPC, the bar and space widths, the edge to similar edge dimensions, and the character to character distance are separately toleranced. Because UPC is a continuous code, with these exacting tolerances it is somewhat difficult to print with devices other than printing presses.

The data security of UPC is difficult to analyze because of its complex structure. An analysis of the proposed IBM symbol, which was structurally similar to the final UPC, a first read rate of 99.5 percent and a corresponding

substitution error rate of one in 145,000 characters was achieved with a fixed head laser scanner as used in U.S. supermarkets.

The actual substitution error probability for source printed UPC is unknown and may differ widely depending on the design and manufacturer of specific scanners and degree to which scanned symbols conform to specification. When UPC is scanned at the supermarket point of sale an important second level of checking is available. This second level of checking is accomplished by a file look-up operation in which the 11 (or 12) digits read from the UPC symbol by the scanner are matched with UPC numbers in the store file. An occasional substitution error by the scanner will, with high probability, produce a UPC number which is not in the store file. With 10,000 items on file, one might infer that the chances of an erroneous 11-digit number coming out of the scanner and being on file are one in 10,000,000. A different situation prevails for random weight items such as fresh meat or cheese, which are sold by weight and for which the item price is contained in the UPC symbol. For these random weight UPC symbols a second check digit covering the price field is strongly recommended in the UPC guidelines. Experience has shown that it is prudent to utilize this second price check digit.

Both UPC and EAN are excellent, well conceived symbologies for use in supermarket point-of-sale systems and

related applications. Characteristics of this application include numeric only data in fixed length fields, a preponderance of symbols printed inexpensively and in high volume by printing presses and a system context providing a high level of data checking (file matching) for the majority of the scanned symbols. Because most other bar code applications have different requirements and conditions, the UPC symbol is seldom recommended and rarely used outside its retail context. A comparison of UPC/EAN to six other bar code symbologies is included in Table D.1.

7. OTHER BAR CODE SYMBOLS

Each of the six bar code symbologies described in the preceding sections has distinguishable merit, a history of successful use, and broad support. Four of the six are embodied in industry standards. This section reviews bar code symbologies which are or have been supported by individual equipment manufacturers and presents a list of lesser known symbologies.

a. Plessey Code

Plessey Code was developed by the Plessey Company in England with formal specifications first dated March 1971. Plessey Code has been extensively used in libraries. A variation of Plessey Code and the associated scanning equipment was provided by Plessey to the ADS Company and this variation is known as Anker Code. Anker Code was used in European point-of-sale systems prior to the advent of

EAN. The basic encoding principle in Plessey Code was used by MSI Data Corporation to construct its MSI bar code, sometimes known as modified Plessey Code. The primary application for MSI Code is marking of retail shelves and subsequent scanning with portable devices to accomplish inventory reordering.

In Plessey Code each character consists of four bars and the adjacent four spaces. Each bar space pair contains one information bit. Zero bits consist of a narrow bar followed by a wide space, while one bits consist of a wide bar followed by a narrow space. For Plessey and Anker Code the zero bit is approximately a one unit bar followed by a four unit space and the one bit is a three unit bar followed by a two unit space. With these relationships each character consumes 20 units of width, which yields lower density than is typical for a numeric symbology. The complete Plessey symbol includes a start character, some number of data characters, an eight bit cyclic check, a termination bar and usually a reverse start character.

In MSI Code, the zero bit is a one unit bar followed by a two unit space and the one bit is a two unit bar followed by a one unit space. Complete four bit characters are thus 12 units wide. The MSI symbol includes a start pattern, data characters, one or two check digits and a stop pattern.

The generic name for the Plessey Code family is pulse width modulated. These symbols are continuous and are not self-checking. They are usually used in fixed length format and are limited to the 10 digits plus six additional characters. Pulse width modulated symbols offer no important technical advantage over the more modern symbologies. An example of the Plessey Code symbol was shown in Figure D.1.

b. Two of Five Matrix

Matrix Two of Five code is a variation of CODE 11 devised by the Nieaf Company in the Netherlands. It is limited to the 10 digits and a start/stop character.

Matrix Two of Five is discrete but not self-checking, and is used with a single modulo 10 check digit. Compared with CODE 11 (using two check digits) and the other industrial symbologies, Matrix Two of Five is somewhat more subject to substitution errors and offers no particular advantage.

c. Nixdorf Code

Nixdorf bar code was introduced in Europe by the Nixdorf Computer Company in the early 1970's. The largest area of application was department store point-of-sale systems.

Nixdorf bar code is numeric, discrete, and self-checking, but the symbol also employs a check digit. Each character consists of three bars and the two contained

spaces. Three different bar widths are used (1 unit, 2.25 units, and 3.75 units).

The sponsorship for Nixdorf Code has been confined to the Nixdorf Company. With the advent of EAN Code in Europe, it is likely that it will largely supersede the use of Nixdorf. An example of the Nixdorf Code was shown in Figure D.1.

d. Delta Distance A

The concept of Delta Distance A Code was introduced by IBM in 1971.

Delta Distance A is a discrete, extended numeric (16 total characters) symbol. Characters are composed of six narrow bars with variable width spaces between the bars. The motivation behind Delta Distance A was to devise a symbology with relatively small but constant printing area for each character which could be printed with formed font type computer line printers. Sponsorship of Delta Distance A has been confined to IBM.

e. Ames Code

Since 1974, Ames Code has been printed on file folders by the Medical Records Systems Division of Ames Color File Corporation. Ames Code is a discrete, self-checking numeric bar code with structural similarity to Codabar. An example of the Ames Code symbol was shown in Figure D.1.

f. Telepen

From 1977 through most of 1981, the leading bar code equipment manufacturers refrained from introducing any new symbologies. During this period companies cooperated through trade associations to standardize several of the proven industrial bar codes. But in 1981, S.B. Electronics, an English company, began intensively promoting its Telepen bar code in the United States. They claimed that Telepen offered higher density than CODE 39 or Interleaved Two of Five and implied that it was the only bar code capable of representing all 128 ASCII characters.

Telepen code employs 16 modules (or units) per character, with black modules representing one bits and white modules representing zero bits. Elements are either one module wide or three modules wide. Individual characters may contain four, five, six, seven, or eight bars. The character set includes 128 characters corresponding to the complete ASCII set. Alternatively, each Telepen character can represent a pair of numeric digits. Provision is made to switch between alphanumeric and numeric representation using embedded control characters. Telepen code uses a variable number of bars per character, is continuous, and despite the claim of its promoters is not self-checking. The specifications define a single check character which is the only means of providing data security. The foregoing properties suggest that the substitution error rate for

Telepen bar code may be higher than that of the established industrial bar codes at comparable print quality.

Because Telepen code requires 16 units of width per alphanumeric characters or eight units per digit in its numeric form, it offers no density advantage over CODE 39 or Interleaved Two of Five. Considering its structural disadvantages, there is no valid technical reason why a prospective user should opt for Telepen bar code.

g. CODE 128

After Telepen had reopened Pandora's box of symbology, two U.S. manufacturers of bar code equipment, Computer Identics and INTERMEC, decided independently to introduce new higher density alphanumeric bar codes.

CODE 128 was introduced by Computer Identics in the fall of 1981. The name CODE 128 derives from its ability to encode 128 different data characters. CODE 128 offers higher density (at constant unit size) than the established industrial symbols, but this is achieved by sacrificing some desirable properties.

The structure of CODE 128 is akin to that of UPC. This structure facilitates decoding using edge to similar edge measurements, a technique that is inherently immune to uniform ink spread. CODE 128 is structured as a 11, 3 code, and as such, is capable of representing 252 possible characters. However, its authors have chosen to use only 107 of the 252 possible characters.

Characters in CODE 128 consist of three bars and three spaces such that total character width is 11 modules. Bars and spaces may be one, two, three, or four modules wide. There are 107 different characters including three different start characters and a stop character. The choice of start code selects one of three possible character sets, so that 128 different ASCII characters can be represented. In one of these character sets each character represents two decimal digits, thus doubling the code density for numeric only data. Various control, function, and shift characters are defined allowing switching between character sets within a symbol.

CODE 128 is continuous and non self-checking when using the preferred edge to similar edge measurements. As with UPC, printing must conform simultaneously to three tolerance constraints. By comparison the less complicated industrial codes tolerance only the bars and spaces. A prospective user of CODE 128 should verify that the symbols which he requires can be properly printed by all required printing devices and methods.

CODE 128 offers a higher density in modules per alphanumeric character or modules per numeric digit than were previously available. However, the minimum nomina module in CODE 128 is .010 inch resulting in a maximum density of 9.1 alphanumeric characters or 18.2 digits per inch. For comparison, CODE 39 and Interleaved Two of Five

printed using .0075 inch units yield 9.4 alphanumeric characters and 17.8 digits per inch, respectively. A further comparison of CODE 128 with six other symbologies is presented in Table D.1.

h. <u>CODE 93</u>

Among the industrial bar codes, CODE 39 is the pre-eminent symbology. The only technical limitation of CODE 39 is that each character consumes 13 to 16 units of width. This limitation is inconsequential except where printing equipment constraints impose a minimum size on individual bar widths (for example, matrix line printers).

The introduction of CODE 93 by INTERMEC in April 1982 was not only in response to Telepen, but also as a compatible solution to the CODE 39 problem.

CODE 93 is a very high density alphanumeric symbology designed explicitly as a companion to CODE 39. The set of data characters in CODE 93 is identical to that of CODE 39. Self-discriminating bar code readers or scanners can read either CODE 39 or CODE 93 without operator intervention. This designed-in compatibility allows CODE 93 symbols to be introduced into existing systems with minimal impact.

The name CODE 93 derives from the (9, 3) notation. Each character consists of nine modules arranged into three bars and three spaces. Forty-eight of the 56 possible combinations are used in CODE 93. One of these characters is reserved for a stop/start character, four are used for

control characters, and the 43 remaining data characters are identical to those in CODE 39. A termination bar is added after the stop character to close off the final space.

CODE 93 is continuous and non self-checking. Bar and space widths may be one, two, three, or four modules wide. Its structure facilitates using edge to similar edge decoding. The resulting symbol is inherently immune to uniform ink spread, which allows liberal bar width tolerances.

CODE 93 uses two check characters in a manner similar to CODE 11 and analogous to the price field in a UPC random weight symbol. By using two check characters, the data security of CODE 93 is even better than that of CODE 39.

CODE 93 is the highest density alphanumeric bar code. It uses nine modules per character compared with 11 modules in CODE 128 and 13 to 16 modules in CODE 39. The minimum nominal module in CODE 93 is 0.008 inch resulting in a maximum density of 13.9 alphanumeric characters per inch. CODE 93 is compared with six other symbologies in Table D.1.

i. <u>Miscellaneous Symbologies</u>

A fair number of lesser known symbologies have been applied by individual sponsoring companies. Some of these include:

- AGES
- AS-6

- AS-10
- F2F
- Fujitsu
- Norand (version of F2F)
- RTC
- Toshiba

TABLE D.1

COMPARISON OF SELECTED BAR CODE SYMBOLOGIES

	Interleaved 2 of 5	CODE 39	Codabar	CODE 11	UPC/EAN	CODE 128	CODE 93
Date of Inception	1972	1974	1972	1977	1973	1981	1982
Standard Specifications	AIM* ANSI	AIM** ANSI	CCBBA ANSI	AIM	UPCC IAN	AIM	AIM
Government Support		DOD					
Corporate Sponsors	C. Identics	INTERMEC	Welch Allyn	INTERMEC		C. Identics	INTERMEC
Most Prominent Application Area	Industry	Industry	Medical	Industry	Retail	New	New
Variable Length	No (1)	Yes	Yes	Yes	No	Yes	Yes
Alphanumeric	No	Yes	No	No	No	Yes	Yes
Discrete	No	Yes	Yes	Yes	No	No	No
Self-Checking	Yes	Yes	Yes	No	Yes	Yes	No
Constant Character Width	Yes	Yes	Yes (2)	Yes	Yes	Yes	Yes
Simple Structure (2 Element widths)	Yes	Yes	No	No	No	No	No
Number of Data Characters In Set	10	43/128	16	11	10	103/128	47/128
Density (3): Units Per Character	7-9	13-16	12	8-10	7	11	9
Smallest Nominal Bar-in.	.0075	.0075	.0065	.0075	.0104	.010	.008
Maximum Char. Per Inch	17.8	9.4	10	15	13.7	9.1	13.9
Specified Print Tolerance At Maximum Density — Bar Width-in.	0.0018	0.0017	0.0015	0.0017	0.0014	0.0010	0.0022
Edge-Edge-in.					0.0015	0.0014	0.0013
Pitch-in.					0.0030	0.0029	0.0013
Does print tolerance leave more than half of the total tolerance for the scanner?	Yes	Yes	No	Yes	No	No	Yes
Data Security (4)	High	High	High	High	Moderate	High	High

NOTES FOR TABLE D.1

* Interleaved Two of Five is also specified by UPCC for use on outer shipping containers and is one of two symbologies specified by the AIAG.

** CODE 39 is also specified by the AIAG and by HIBC.

1. Interleaved Two of Five is fundamentally a fixed length.

2. Using the standard dimensions Codabar has constant character width. With a variant set of dimensions, width is not constant for all characters.

3. Density calculations for Interleaved Two of Five, CODE 39, and CODE 11 are based on a wide to narrow ratio of 2.25 to 1. Units per character for these symbols is shown as a range corresponding to wide/narrow ratios from 2 to 3. A unit in Codabar is taken to be the average of narrow bars and narrow spaces giving about 12 units per character.

4. High data security corresponds to less than one substitution error per several million characters scanned using reasonably good quality printed symbols. Moderate data security corresponds to one substitution error per few hundred thousand characters scanned. These values assume no external check digits other than those specified as part of the symbology and no file lookup protection or other system safeguards.

APPENDIX E

MIL-STD-1189A

This appendix is a reproduction of MIL-STD-1189A and is included as an integral part of this thesis. It defines the Standard Department of Defense Bar Code Symbology (SDS) for marking materiel, containers, and documentation by means of bar coding.

SUPERSEDES
MIL—STD 1189
4 JANUARY 1982

4 SEPTEMBER 1984

MIL—STD—1189A

MILITARY STANDARD

STANDARD DEPARTMENT OF DEFENSE BAR CODE SYMBOLOGY

No Deliverable Data Required by This Document

AREA PACK

DEPARTMENT OF DEFENSE

Washington, DC 20402

Standard Department of Defense Symbology (SDS)

MIL-STD-1189

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, AMC Packaging, Storage, and Containerization Center, ATTN: SDSTO-TP, Tobyhanna, PA 18466, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

CONTENTS

1. SCOPE

1.1 <u>Purpose</u>. The purpose of this standard is to define the Standard Department of Defense Bar Code Symbology (SDS) for marking materiel, containers, and documentation by means of bar coding.

1.2 <u>Application</u>. The SDS shall be used whenever bar code marking and reading operations are employed within logistics operations.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issues in effect on the date of invitation for bids or request for proposal form a part of this standard to the extent specified herein.

Recommended Practices for Uniform Container Symbol (UCS). Transport Case Symbol (TCS) by the Distribution Symbology Study Group is available from the Automatic Identification Manufacturers (AIM), a product section of the Material Handling Institute, Inc., 1326 Freeport Road, Pittsburgh, PA 15238.

MIL-STD-105. Procedures and Tables for Inspection by Attributes.

3. DEFINITIONS

3.1 Bar. The darker element of a bar code.

3.2 Bar code. An array of rectangular bars and spaces in a predetermined pattern.

3.3 Bar width. The perpendicular distance across a bar measured from a point on one edge to a point on the opposite edge. Each point will be defined as having a reflectance that is 50 percent of the difference between the background and bar reflectances.

3.4 Bearer bar. A rectangular bar pattern circumscribing the bar code, particularly a bar code directly printed on corrugated fiberboard.

3.5 Bidirectional code. A bar code format which permits reading in complementary (opposite) directions across the bars and spaces.

3.6 Binary. Pertaining to a characteristic or property involving a selection, choice, or condition in which there are two possibilities.

3.7 Binary code. A code which makes use of exactly two distinct characters, usually 0 and 1.

3.8 Certificate of Conformance (COC). Contractor's signed certification that the supplies provided to the Government (under contract) comply with stated contract requirements and specifications. The COC does not waive the Government's right to inspect supplies under other inspection provisions of a contract.

3.9 Character. Letter, digit, or other special form that is used as part of the organization, control, or representation of data. A character is often in the form of a spatial arrangement of adjacent or connected strokes.

3.10 Character set. Those characters which are available for encoding within the bar code.

3.11 Code density. The number of characters that can appear per unit of length, normally expressed in characters per inch (CPI).

3.12 Discrete code. A bar code in which the intercharacter gap is not part of the code and is allowed to vary dimensionally within wide tolerance limits.

3.13 Element. A generic term used to refer to either a bar or a space.

3.14 Human Readable Interpretation (HRI). The exact interpretation of the encoded bar code data presented in a human-readable font.

3.15 Intercharacter gap. The space between the last element of one character and the first element of the adjacent character of a discrete bar code.

3.16 Margin (quiet zone). The area immediately preceding the start character and following the stop character, which contains no markings.

3.17 Message. The string of characters encoded in a bar code.

3.18 Print Contrast Signal (PCS). A measure of the contrast between the bars and spaces of a symbol. It is based on reflectance measurements at a specified wavelength of light.

3.19 SDS (Standard DOD Bar Code Symbology). The 3 of 9 bar code with a human-readable interpretation (HRI) printed above or below the 3 of 9 bar code. The 3 of 9 bar code is defined in terms of size, density, contrast, and code pattern.

3.20 Self-checking bar code. A bar code which uses a checking algorithm which can be applied against each character to guard against undetected errors.

3.21 Space. The lighter element of a bar code.

3.22 Start and stop character. A distinct character represented by an asterisk (*), used at the beginning and end of each 3 of 9 bar code which provides initial timing references and direction of read information to the coding logic. The asterisk start and stop code is an integral part of and peculiar to the 3 of 9 bar code.

3.23 Symbol. A complete bar code containing margins, start character, data characters, check digit (if any), and stop character.

3.24 Unit size. The bar width of the narrow element. (The narrow bar and the narrow space are equal in the 3 of 9 bar code.)

4. GENERAL REQUIREMENTS

4.1 <u>3 of 9 bar code description</u>. The 3 of 9 bar code is a variable length, discrete, self-checking, bidirectional, alphanumeric bar code. Its character set contains 43 meaningful characters: 0-9, A-Z, -, ., $, /, +, %, and space. Each character is composed of nine elements: five bars and four spaces. Three of the nine elements are wide (binary value 1), and six elements are narrow (binary value 0). An additional common character (*) is used for both start and stop delimiters. Table E.1 presents the code symbology for the 3 of 9 bar characters.

4.2 <u>Human-readable interpretation (HRI)</u>. The HRI of the 3 of 9 bar code shall represent only the encoded characters. The HRI is intended to be used only for human recognition and is not intended to be machine readable. For example, a national stock number (NSN) normally would be marked as 5960-00-127-4329. However, when bar coded, only the 13 digits are to be encoded and the HRI will be marked equally as 5960001274329. Note that the start and stop asterisks shall be suppressed when printing the HRI. The shapes and sizes of the characters can be in an easily read font and are to be a minimum of 0.094 inches (2.39 mm) in height. The HRI shall be printed above or preferably below the bar code.

4.3 <u>SDS configuration</u>. An SDS message consists of a number of 3 of 9 bar code data character symbols enclosed between two start and stop code characters, with the HRI characters printed above or below the bar codes. An example of an SDS message containing the data string "ABC" is shown in Figure E.1. The dimensioning requirements are detailed in section 5.2. The code configurations for 3 of 9 bar code characters are listed in Table E.1.

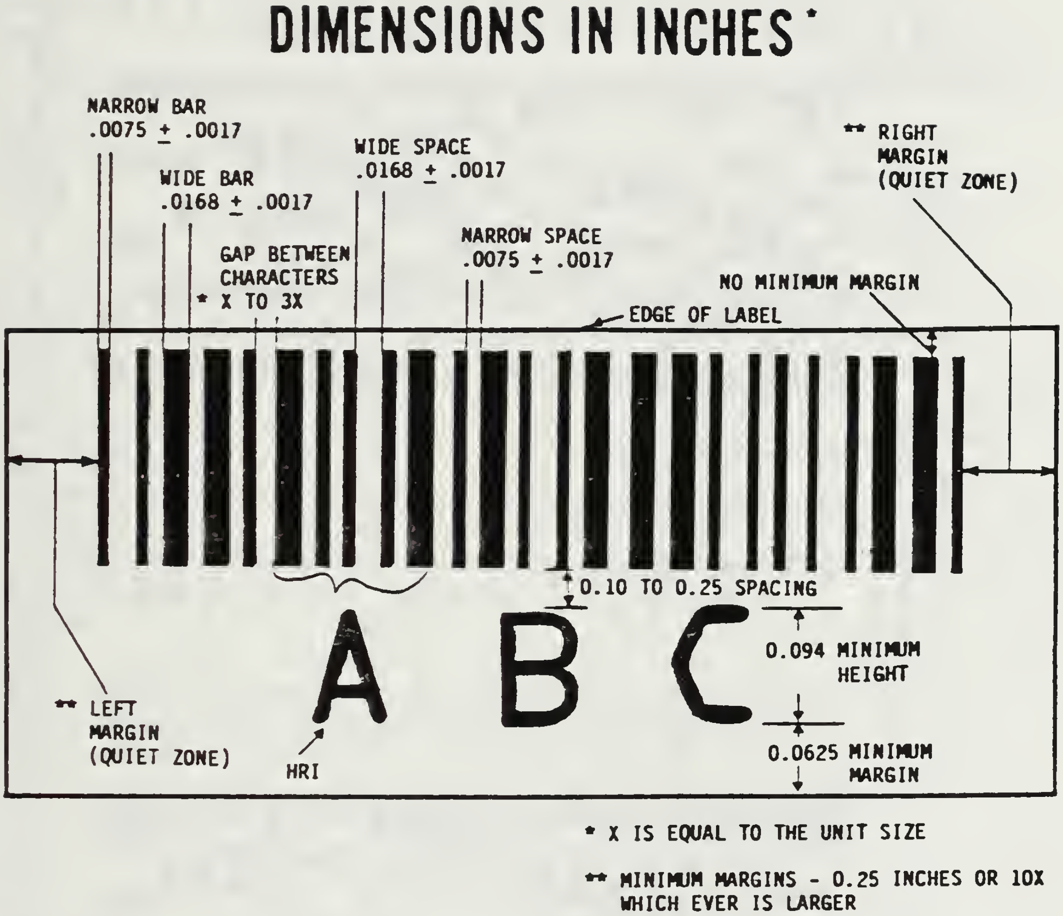


Figure E.1 Example SDS with a High-density Bar Code of 9.4 Characters Per Inch (CPI) (Enlarged)

TABLE E.1

CODE CONFIGURATION

CHAR.	PATTERN	BARS	SPACES	CHAR.	PATTERN	BARS	SPACES
1		10001	0100	M		11000	0001
2		01001	0100	N		00101	0001
3		11000	0100	O		10100	0001
4		00101	0100	P		01100	0001
5		10100	0100	Q		00011	0001
6		01100	0100	R		10010	0001
7		00011	0100	S		01010	0001
8		10010	0100	T		00110	0001
9		01010	0100	U		10001	1000
0		00110	0100	V		01001	1000
A		10001	0010	W		11000	1000
B		01001	0010	X		00101	1000
C		11000	0010	Y		10100	1000
D		00101	0010	Z		01100	1000
E		10100	0010	-		00011	1000
F		01100	0010	.		10010	1000
G		00011	0010	SPACE		01010	1000
H		10010	0010	*		00110	1000
I		01010	0010	$		00000	1110
J		00110	0010	/		00000	1101
K		10001	0001	+		00000	1011
L		01001	0001	%		00000	0111

The * symbol denotes a unique start/stop character which must be the first and last character of every bar code message.

5. PRINT REQUIREMENTS

5.1 Reflectivity and contrast.

5.1.1 Reflectivity.

5.1.1.1 Light sources. Three spectral bands are referenced:

Spectral Band	Wave Length (Peak Nanometers)	Maximum Band Width 50% Level (Nanometers)
B633	633 ± 5%	120--visible
B800	800 ± 5%	40--laser diode
B900	900 ± 10%	40--invisible (infrared)

These bands represent spectral responses required from the measuring instrument (light source, filter, detector). Band B633 corresponds with scanners using sources emitting visible red light within the B633 spectral band. Band B800 corresponds to reading devices that respond to laser diode light sources that emit light within the B800 band. Band B900 corresponds to reading devices that use light sources and appropriate detectors operating in the near infrared. All the measurements shall be made in the final package configuration as it is to be scanned. Some printing processes such as those using inks containing carbon will easily achieve adequate contrast in all three spectral bands. Other printing processes such as those using various colored dyes may satisfy the requirements of the B633 band but not for the B800 or B900 bands. As a minimum, the printed bar code symbol shall meet the contrast and reflectivity requirements for band B633 using barium sulfate ($BaSO_4$) or magnesium oxide (MgO) as a photometric standard. Reflectivity measurements shall be made with incident irradiation at 45^o from a normal (perpendicular) to the surface and reflected flux collected within a 15^o angle centered on the normal.

5.1.1.2. Opacity. Reflectance values may be measured directly on bar code symbols, which have been printed on a material which has an opacity value exceeding 0.90. The calculated opacity value of a material shall be determined by two reflectance measurements (R_1 and R_2). The first measurement (R_1) shall be taken on a blank material, sample backed with enough layers of the same material so that doubling the number of layers will not change the measured value of reflectance. The second measurement (R_2) shall be taken on the same blank material sample except that a black

backing shall be placed directly behind the material sample instead of multiple layers. The reflectance value of the black backing shall not exceed 5 percent. The calculation of the opacity value is as follows:

$$\text{Opacity Value} = 1.00 - \left(\frac{R_1 - R_2}{R_1}\right) \quad \text{or} \quad \frac{R_2}{R_1}$$

When bar code symbols are to be printed on nonopaque materials with opacity values less than or equal to 0.90, reflectance measurements shall be made on the bar code symbol with a backing material which has a reflectance value equal to that of the bar code symbol backing in the final packaging configuration. When the bar code symbol is applied to the final package configuration, there shall be no greater than 10 percent variation in the reflectance values of the white elements due to the interfering patterns showing through nonopaque bar code symbol materials.

5.1.1.3 <u>Bar reflectivity</u>. The maximum allowable reflectivity of the dark bars is related to the reflectivity of the light spaces. Bar code symbols with spaces that are less reflective will require bars that are "darker" (less reflective). Table E.2 illustrates the maximum bar reflectance R_b as functions of space reflectance R_w. The minimum space reflectance shall be 25 percent for bar code symbols with narrow bar widths equal to or greater than 0.020 inch (0.508 mm). The minimum space reflectance shall be 50 percent for bar code symbols with narrow bar widths less than 0.020 inch (0.508 mm).

5.1.2 <u>Print Contrast Signal (PCS)</u>. The PCS is defined as:

$$PCS = \frac{R_w - R_b}{R_w}$$

where R_w is the reflectance from the white spaces, and R_b is the reflectance from the dark bars. The minimum PCS allowed is 75 percent.

5.2 <u>Code density and dimension</u>. The 3 of 9 bar code can be printed at various densities to accommodate a variety of printing and reading processes. Examples of acceptable densities in CPI are: 9.4 = high; 5.7 = medium; and 3.0 = low. A density of 9.4 CPI is commonly used where space is at a premium. Low density codes are commonly used on exterior shipping containers where lower density codes will facilitate automated materials handling by remote scanners. The significant parameters are the nominal width of the narrow elements (unit size) and the nominal ratio of wide-to-narrow elements. The allowable range for the nominal unit size and the nominal wide-to-narrow ratio is as follows:

TABLE E.2

ALLOWABLE VALUES OF BAR REFLECTANCE

Space Reflectance R_w (%)	Maximum Bar Reflectance R_b (%)
25	6.25
30	7.50
35	8.75
40	10.00
45	11.25
50	12.50
55	13.75
60	15.00
65	16.25
70	17.50
75	18.75
80	20.00
85	21.25
90	22.50
95	23.75
100	25.00

NOTE: In the above table, the minimum contrast ratio of R_w to R_b is 4.0, and the minimum print contrast signal (PCS) is 75 percent.

Minimum nominal unit size - 0.0075 inch (0.190 mm).

Maximum nominal unit size - 0.0400 inch (1.016 mm).

Nominal wide-to-narrow ratio - 2.2:1 to 3.0:1 for codes whose unit size is less than 0.015 inch (0.381 mm).

- 2.0:1 to 3.0:1 for codes whose unit size is equal to or more than 0.015 inch (0.381 mm).

5.2.1 <u>Code height</u>. The bar code height can vary to suit specific reading and printing requirements. The minimum bar height shall be 0.25 inch (6.35 mm). The bar code heights listed in Table E.3 shall be used for the corresponding ranges of bar code density. For those applications where these heights are not suitable, height

requirements will be as specified by the responsible procurement activity.

TABLE E.3

BAR CODE HEIGHTS

Density Range	Minimum Height in	(mm)	Maximum Height in	(mm)
1.7 $\leq$ CPI < 3.0	0.75	(19.05)	1.25	(31.75)
3.0 $\leq$ CPI < 6.5	0.375	(9.53)	0.875	(22.23)
6.5 $\leq$ CPI $\leq$ 9.4	0.25	(6.35)	0.50	(12.7)

5.2.2 <u>Intercharacter gap</u>. The minimum gap between characters is the same as the minimum dimension of a narrow element. The maximum intercharacter gap width shall be no more than three times the width of a narrow element (see Figure E.1).

5.2.3 <u>Margins (quiet zones)</u>. The minimum left and right margins shall be 10 times the width of one narrow element or 0.25 inch (6.35 mm), whichever is greater (see Figure E.1).

5.2.4 <u>Spacing between bar code and HRI</u>. The spacing between the bar code and the HRI shall be a minimum of 0.10 inch (2.54 mm) and a maximum of 0.25 inch (6.35 mm) (see Figure E.1).

5.2.5 <u>Spacing between edge of label and HRI</u>. The minimum spacing between the horizontal edge of the label and the HRI shall be 0.0625 inch (1.588 mm) (see Figure E.1).

5.2.6 <u>Spacing recommendations for SDS message formats</u>. The following spacing requirements apply unless otherwise specified (refer to Figure E.2).

5.2.6.1 <u>Stacked SDS messages</u>. When SDS messages are in an over-and-under configuration (stacked), the messages shall have a minimum separation of 0.375 inch (9.53 mm) and a maximum separation of 0.75 inch (19.05 mm) from bar code to bar code (see Figure E.2).

5.2.6.2 <u>Separated in-line SDS messages</u>. The spacing between two separately coded SDS messages on the same line shall have a minimum separation of 0.5 inch (12.7 mm) (see Figure E.2).

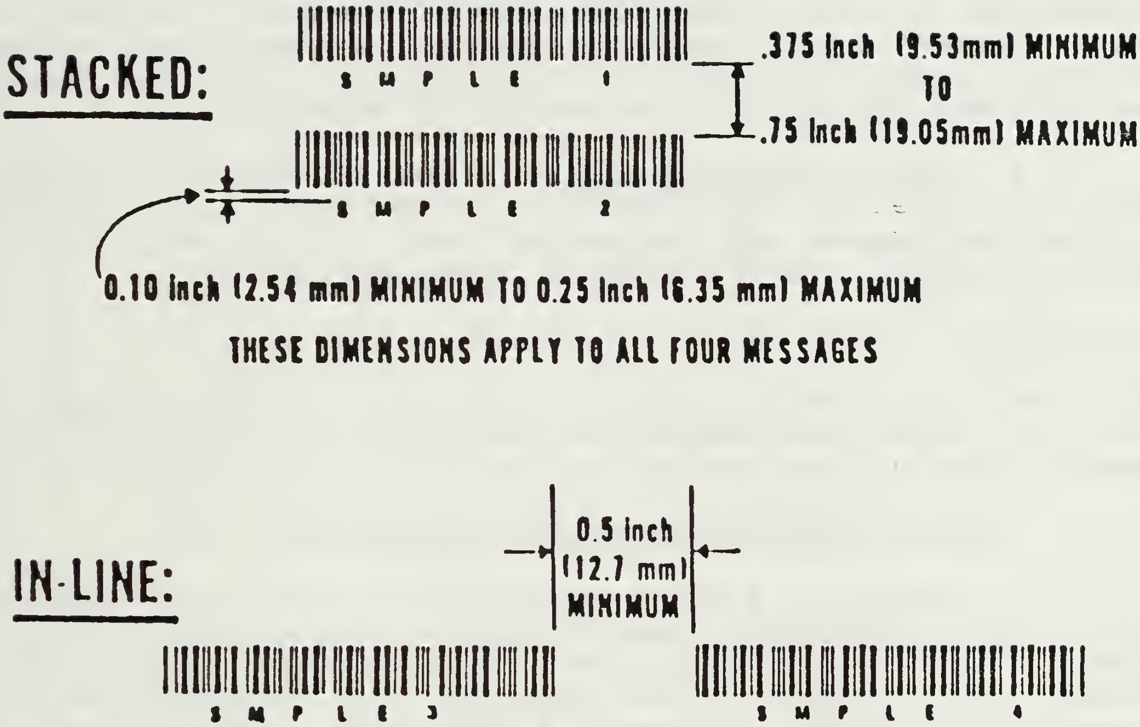


Figure E.2 Spacing for Multiple SDS Message Format

5.2.7 Maximum number of encoded characters. The maximum number of encoded data characters in a single SDS message shall not exceed 30 data characters unless otherwise specified. The total number of encoded characters shall not exceed 32 characters including the start and stop characters and other control characters that may be used.

5.3 Bar code tolerances.

5.3.1 Measuring tolerance. The width of printed bars and spaces can be measured with an optical comparator or electrooptical measuring instruments using reflected light incident at 30^{o} to 45^{o} from a normal to the printed surface. When using a comparitor, a magnification of 50X is recommended although, with some loss of accuracy, 20X may be used. Printed bar codes with reasonably smooth bar edges are easily measured by visually averaging the edge roughness over a linear reticle on the comparitor screen.

5.3.2 Calculating tolerance. The allowable printing width tolerance (t) is a function of the nominal width (x) of a narrow element and the nominal ratio (n) of the wide to narrow elements. This tolerance is defined as:

$$t = \pm(\frac{4}{27})(n - \frac{2}{3})(x) \text{ or } t = \pm .1481(n - .6667)x$$

Note that the value of n shall be in the allowable range of 2 to 3. Table E.4 shows the tolerance for some of the commonly used dimensions and ratios.

5.4 Spots, voids, and bar edge roughness.

5.4.1 General. A major advantage of 3 of 9 bar code is that it can be correctly read in spite of localized printing defects. A defect of sufficient magnitude may cause a wand scanner not to read if the scanning line passes directly through the defect. However, a subsequent scan through a nondefective area of the bar code will typically result in a good read.

5.4.2 Bar edge roughness. A certain degree of bar edge roughness is permitted in the bar and space width tolerances. The white to black and black to white transition points are determined where the apparent reflectance of a circle with a diameter 0.8 times the nominal width of a narrow element is halfway between the reflectances of the bar and space reflectance values.

5.4.3 Spots and voids. Spots and voids which meet either of the following criteria are permitted:

TABLE E.4

TOLERANCES FOR SELECTED DENSITIES

Density CPI	Nominal Narrow (in)	Width (x) Elements (mm)	Wide/Narrow Ratio n	Nominal Width Wide Elements (in)	(mm)	Element Tolerance (t) (in)	(mm)
9.4	0.0075	0.190	2.24	0.0168	0.427	0.0017	0.044
8.6	0.0080	0.203	2.5	0.0200	0.508	0.0022	0.055
7.4	0.0100	0.254	2.2	0.0220	0.559	0.0023	0.058
6.3	0.0100	0.254	3.0	0.0300	0.762	0.0035	0.088
5.7	0.0120	0.305	2.5	0.0300	0.762	0.0033	0.083
5.4	0.0115	0.292	3.0	0.0345	0.876	0.0040	0.101
4.8	0.0160	0.406	2.0	0.0320	0.813	0.0032	0.081
3.9	0.0160	0.406	3.0	0.0480	1.219	0.0055	0.140
3.0	0.0210	0.533	3.0	0.0630	1.600	0.0073	0.184
2.3	0.0300	0.762	2.5	0.0750	1.905	0.0081	0.207
1.7	0.0400	1.016	2.5	0.1000	2.540	0.0109	0.276

5.4.3.1 The spot or void can be contained within a circle whose diameter is 0.4 times the nominal width of the narrow element.

5.4.3.2 The spot or void occupies no more than 25 percent of the area of a circle whose diameter is 0.8 times the nominal width of the narrow element. Larger spots or voids can be expected to reduce the first read rate depending upon their size.

6. PRINTING METHODS

6.1 SDS message printing. Any printing process that produces an SDS message meeting the requirements of this standard may be used.

6.2 Direct printing on corrugated fiberboard.

6.2.1 Printing practices. The specific printing practices for printing SDS messages directly on corrugated fiberboard are described in "Recommended Practices for Uniform Container Symbol (UCS) Transport Case Symbol (TCS)." These practices should be followed for direct printing of SDS messages on corrugated fiberboard. The recommended minimum nominal width of the narrow element for direct printing on corrugated fiberboard shall be 0.020 inch (0.508 mm). For direct printed bar codes, the recommended minimum ratio of the wide-to-narrow element width is 2.5:1. Direct printed bar code densities greater than 1.7 CPI are acceptable when they meet the requirements of this standard.

6.2.2 Bearer bars. A bearer bar is a rectangular bar pattern circumscribing the SDS message horizontally and vertically. A bearer bar may be employed to provide uniform support for the printing plate at critical areas near the SDS message for direct printing on corrugated fiberboard. Recommended dimensions of the bearer bar are also contained in the report referenced in 6.2.1.

7. READABILITY REQUIREMENTS

7.1 Preprinted SDS shall be accepted when it is accompanied by a Certificate of Conformance (COC) that has been provided by the SDS manufacturer and states compliance with MIL-STD-1189A.

7.2 SDS without a COC will be acceptable if the bar code can be successfully scanned. A successful scan is achieved when a bar code is read with three or fewer attempts with a wand-type scanner or two or fewer attempts with a laser scanner. These requirements apply when the scanners are being used in accordance with correct operating procedures. A minimum of 97 percent of the bar codes in a shipment shall be successfully read within the above parameters, and 100 percent of the labels must meet the format requirements. Random sampling is acceptable when conducted in accordance with MIL-STD-105.

7.3 Nonreadability of the bar code will be reason to examine the SDS for compliance with all requirements of this standard. An analysis of the bar code reflectance and dimensions can be performed by electrooptical equipment. No individual bar or space measurements shall exceed the tolerance by more than 50 percent of the tolerance and not more than 10 percent of the measurements of the bars or spaces shall exceed the tolerance by more than 20 percent of the tolerance.

7.4 Inspection of the SDS may be performed after any process that may affect the readability of the bar code. It will be acceptable if the bar code can be successfully scanned, as described in 7.2 above.

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-1189A	STANDARD DEPARTMENT OF DEFENSE BAR CODE SYMBOLOGY

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION (Mark one) ☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER (Specify): ______
b. ADDRESS (Street, City, State, ZIP Code)	

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

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